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A NOVEL REDUCTION GEAR

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Some six years ago a great interest was awakened in the question of the possible adaptability of the steam turbine to marine propulsion. The unusual interest was due to the fact that steam turbines were rapidly replacing reciprocating engines for driving electric generators, and great numbers of them of various sizes were in every-day use in power houses throughout this country and Europe. The popularity of the steam turbine seemed to be well founded, for it had proven itself more economical in steam consumption than the reciprocating engine, occupied vastly less space, required very little foundation, cost less to install, the cost of upkeep was small, and moreover it was extremely reliable in operation. These were the characteristics wanted in a marine engine, but it was not yet proven that they were the characteristics of a marine turbine, and it was to ascertain the exact status of the marine turbine that Mr. George Westinghouse retained Rear Admiral Melville, ex-Engineer in Chief of the United States Navy, and Mr. John H. Macalpine, consulting engineers, to investigate the matter for him. After they had obtained all the information that they possibly could upon this subject, they submitted to Mr. Westinghouse an exhaustive report which was not very favorable to the marine turbine. They pointed out that it would be injudicious to apply the turbine to other than very fast ships, which would run only a small proportion of the time at cruising speed, and even for such cases the advantages had, in their opinion, been over-rated.

They pointed out that the principal disadvantage of the steam turbine for marine propulsion was that even when the speed of revolution of propeller was so high that it was comparatively inefficient, the turbine was running at a speed which was slow for turbines and as a result marine turbines were bulky and not at all efficient as compared with land turbines. In concluding their report they say:

"If one could devise a means of reconciling in a practical manner the necessary high speed of revolution of turbine with

the comparatively low rate of revolution required by an efficient propeller the problem would be solved and the turbine would practically wipe out the reciprocating engine for the propulsion of ships. The solution of this problem would be a stroke of great genius."

It is what we consider to be a solution of this problem that we wish to discuss in this paper, and it is interesting to note that this has been accomplished in a most practical manner by the very men who propounded it some six years ago. The necessary financial assistance to test the proposed device was in this case furnished by the man who instigated the investigation.

Various schemes have been devised to accomplish the speed reduction, one idea being to use a steam turbine to drive an electric generator furnishing power for motors on the propeller shafts. This scheme would have the advantage of extreme elasticity of arrangement as the turbine and condenser could be located where most favorable instead of having its position determined by the propeller shaft. This plan involves heavy and costly machinery, and moreover serious complication for varying the speed of the motors, an obvious disadvantage. The really fatal defect, however, is the loss of power in the generator and motor. Mr. Emmet in his paper before the Society of Naval Architects and Marine Engineers* claims that the efficiency of transmission, or, as he styles it, the "Electric Bond," should be about 92%. But Dr. Fottinger of the Vulcan Company of Stettin, who made a number of experiments with various electrical arrangements was not able to show a higher combined efficiency of generator and motor than 87%.

This low efficiency of electric transmission led Dr. Fottinger to look for other means of transmitting the power at a reduced speed, and he subsequently devised a very ingenious scheme which consists of two water wheels, one connected to the turbine and imparting velocity energy to the water and the other, which is coupled to the propeller, is designed to absorb the energy so developed. The latter doing this in two stages gives the desired reduction of speed. We understand that the Vulcan Co. have patented this idea and have conducted a large number of tests to determine the efficiency and practicability of the device. The efficiency as quoted in London "Engineering," November 5th, 1909, varies from 78% to 83%, depending upon the speed reduction.

The scheme proposed by Messrs. Melville and Macalpine is to use a high speed turbine and transmit the power to a slow speed propeller through a mechanical reduction gear.

It has been generally admitted that properly cut gears will transmit power with extremely small loss, but the use of gears for large work has heretofore been limited owing to mechanical difficulties involved. It, therefore, remained for Messrs. Melville

* Read at Meeting in New York on November 19th, 1909.

and Macalpine to invent a gear which would transmit the enormous powers necessary for the propulsion of large, fast ships at a speed of revolution of pinion which would permit of a design of turbine giving the lowest possible steam consumption, and would reduce the speed of revolution to that required for best propeller efficiency. Ordinary gears will not do this: that is, they can not be operated successfully with wide gear faces working with several hundred pounds pressure per inch of width of tooth, while revolving at a velocity of over a mile a minute at the pitch line. And this for the manifest reason that if it was humanly possible to accurately cut and align the gears so that there would be a line contact to begin with, this condition would not be maintained for any length of time because of the natural wear of the bearings. Without this fine alignment the load would become concentrated at the ends of the teeth so that they would fail by breaking or would wear rapidly.

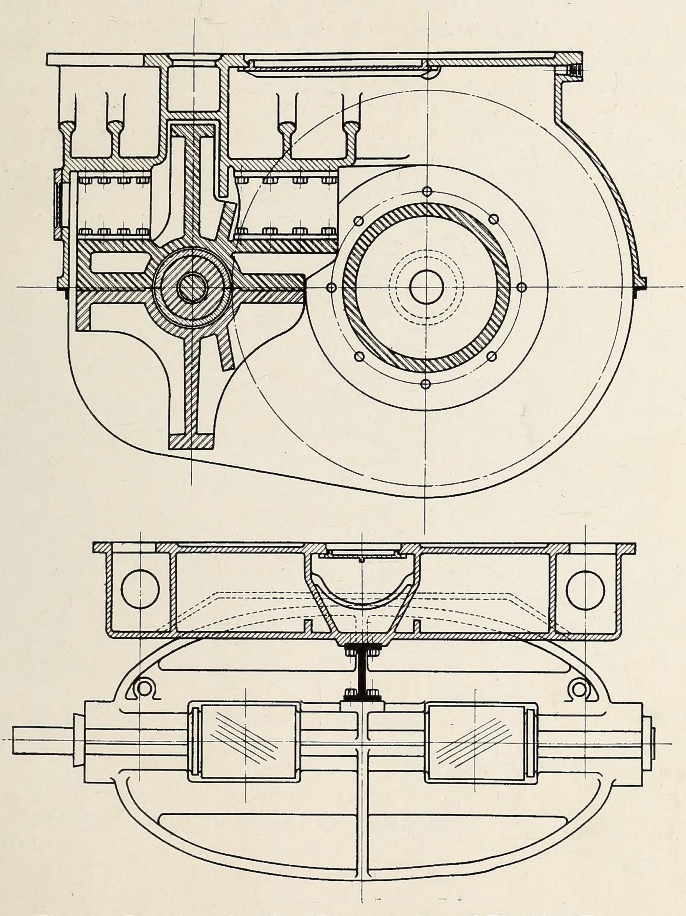


Fig. 1—Drawing showing Construction of Floating Frame.

High speed gears have been employed by the DeLaval Turbine Company for some time, but of limited power, as understood not greater than 300 H.P., or preferably less, while the demands for marine work may be twenty or thirty thousand horse power.

The novel feature of the Melville and Macalpine reduction gear consists in carrying the pinion shaft in what the inventors call a "floating" frame. Referring to Fig. 1 it will be noted that the floating frame is extremely stiff in itself and supported halfway between the end bearings in such a way that it is free to oscillate in the vertical plane passing through the axis of the pinion shaft—however, prevented from moving in other directions. The result of this arrangement is that any minute irregularity in the pitch of the teeth (which would tend to concentrate the load) will merely cause the floating frame to change its position about its central support and in this way equalize the pressure. It will be observed, therefore, that the pinions automatically adjust themselves to divide the load and so avoid abnormal stresses. In order to transmit the enormous power required in marine work, it is not necessary to have very wide gears, and it is found advantageous to divide this into two gears on the same shaft. Helical teeth are employed so that they will roll into contact without shock and thus reduce wear and noise. The helix described by the teeth on one gear is right hand and

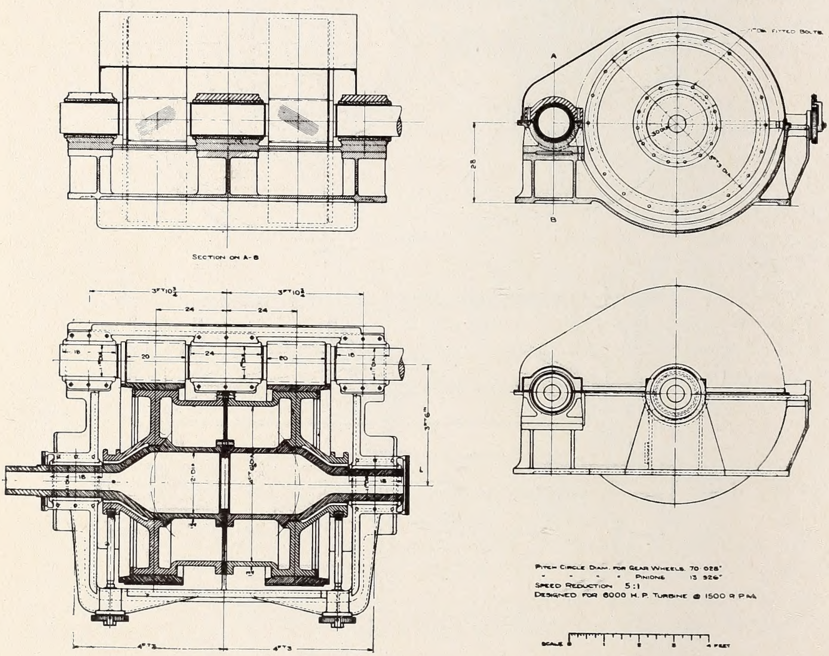


Fig. 2—Drawing showing Construction of Reduction Gear with Flexible Diaphragm.

on the other left hand so that the end thrust, due to the horizontal component of the pressure on the teeth, is balanced. In addition to this the pinion shaft is free to move endwise in its bearings so that it can not resist a greater end thrust at one end than at the other, and will therefore automatically divide the load between the two pinions. This feature made it necessary to design a special coupling which will be described later.

In this connection it will be interesting to note that Mr. George Westinghouse has developed a modification of this gear which differs from the "floating frame" type in that both the pinion shaft and the gear shaft are carried in fixed bearings, the connection between the gear rim and the shaft being made through a thin diaphragm, which while amply strong to transmit torque, is sufficiently flexible to permit of the gears aligning themselves by interaction of the tooth pressures. The general construction is shown in Fig. 2, the other details being the same as those described in connection with the "floating frame" gear.

The construction of the floating frame gear is illustrated in Fig. 3, parts being shown broken away to expose one of the

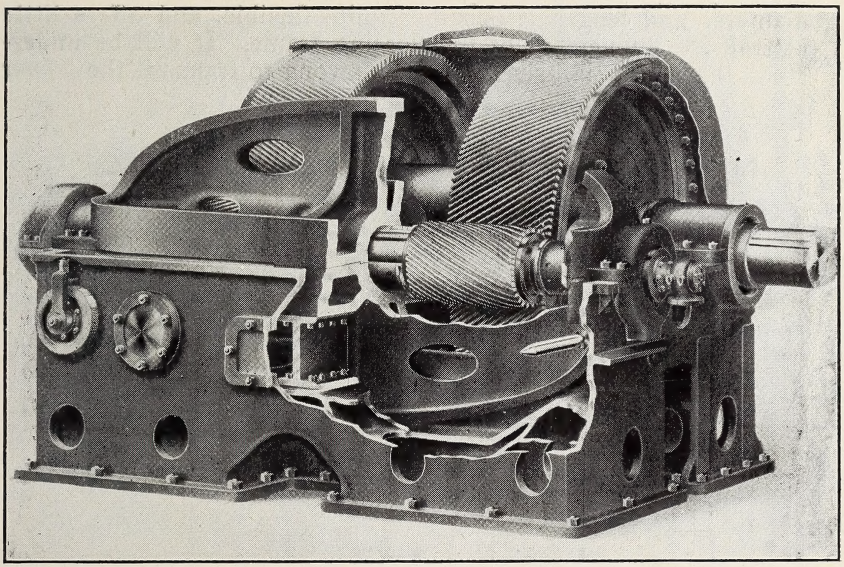


Fig. 3—Reduction Gear with Part of Floating Frame broken away to show Construction and Pinion.

pinions. It will be noticed that the flexible support of the pinion frame consists of an I-beam so arranged that the web is free to bend back and forth as required. Fig. 1 shows two sections through the main frame of this gear illustrating the arrangement of this I-beam and the floating frame a little more clearly. As this beam upon which the floating frame is supported, not

only permits of a motion in the vertical plane through the centre line of the pinion shaft but is insufficient to resist the forces in a plane at right angles, consequently it is necessary to prevent motion due to this latter stress, and this is accomplished by having a strut placed at each end of the main bedplate between the latter and the floating frame as shown at Fig. 3. These

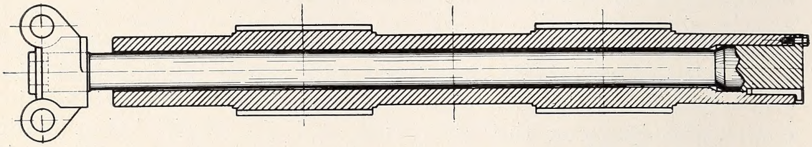


Fig. 4—Drawing showing Construction of Pinion and Flexible Pinion Shaft.

struts are capable of being adjusted so that each pinion meshes equally with its main gear.

Fig. 4 shows the pinion and the pinion shaft separate from the gear and frame, and it will be noticed that the shaft passes completely through the pinion shell to the end farthest from the coupling and is here keyed and bolted. By virtue of its small diameter and length it becomes quite flexible, and offers little restraint to movement of the floating frame. It will be understood that this small shaft is amply strong to transmit the power

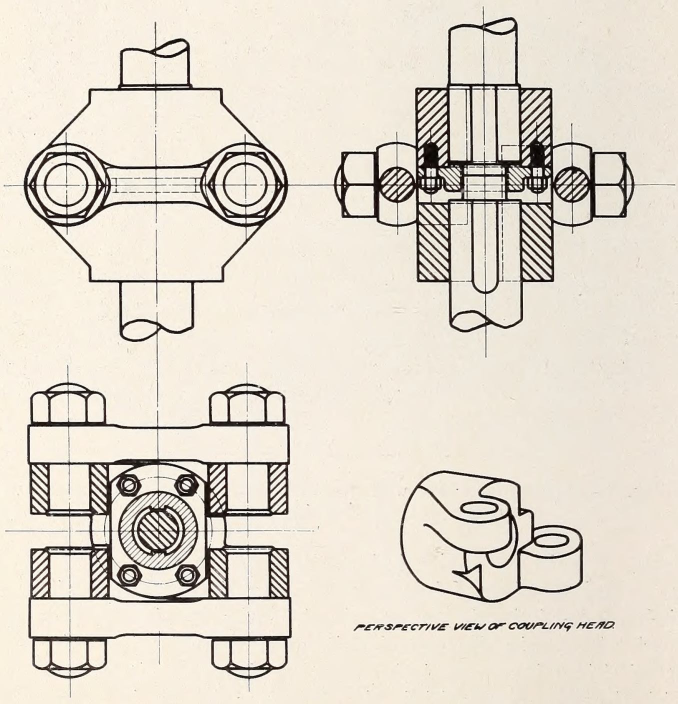


Fig. 5—Drawing showing Construction of Coupling.

of the turbine to the pinion shell on account of the high speed of revolution.

The coupling used between the turbine and pinion is shown in Fig. 5. It is obvious that this coupling permits of necessary freedom to end motion and is quite adequate for any small misalignment.

The lubrication of the teeth is effected by spraying oil on the pinion teeth just prior to the moment they come in contact with the teeth of the gear. This secures most efficient lubrication for the reason that the oil can only escape between the surfaces of the teeth in contact. The large quantity of oil so sprayed upon the teeth not only lubricates them but serves to effectively keep down the temperature. The oil is collected and cooled before being returned to the gears.

In order to determine the efficiency of the gear and ascertain what load it would carry, Mr. Westinghouse had one built and subjected to rigid and exhaustive tests. With his characteristic desire to obtain results, that would not be open to question, he had the gear built large enough to transmit 6000 H.P., this

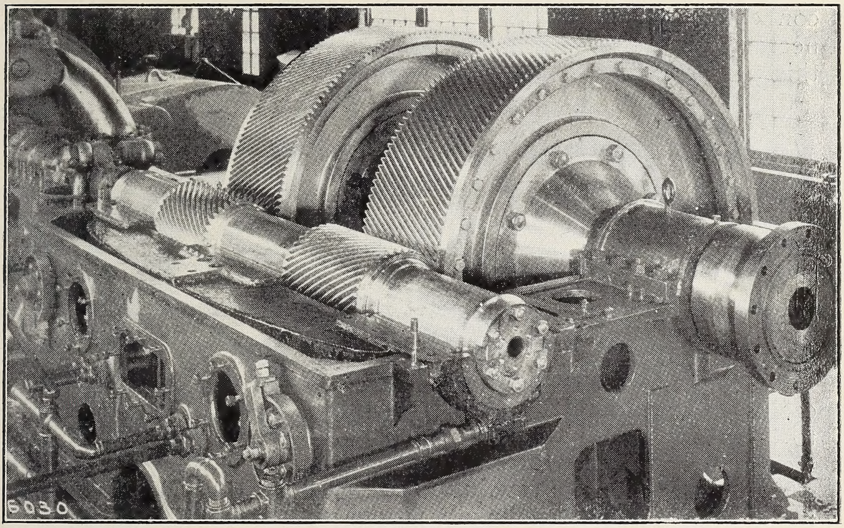


Fig. 6—Photo of Gear with Cover and Upper Half of Floating Frame Removed to Expose Pinion and Gear.

being as large as the boiler capacity of the Westinghouse Machine Company's power plant would permit of testing, and it was surely large enough to be considered full size and not an experimental model.

Fig. 6 shows a photograph of this gear with the cover and the upper half of the floating frame removed, a portion of the turbine which drives the gear being shown in the upper left-hand corner of the illustration.

The pitch diameter of the pinion is about 14″, and that of the large gear about 70″, the width of face of each being 20″. This particular gear was designed for a speed of 1500 R.P.M. of the pinion shaft, reducing to about 300 R.P.M. at the driven shaft. The pinions have thirty-five teeth each, and the large gears one hundred and seventy-six teeth, a hunting tooth being provided to equalize wear. The circumferential pitch of the teeth is 1¼″ and the helices described by the teeth are at an angle of 30° with the axis of the shaft. Involute teeth are used because they will permit of some latitude in the distance between centres of gear and pinion without any sacrifice of their operating qualities. The space occupied by the machine is approximately 11 feet long by 9 feet wide by 7 feet high.

On analyzing the forces in this gear, it will be found that in order to transmit 6000 H.P. there will be a pressure of 453 pounds per inch of length of tooth. It will also be noted that the speed at the pitch line is about 5500 ft. per minute.

The testing of this gear is an interesting problem, the method of solving which might be briefly discussed. A steam turbine capable of developing over 6000 H.P. at 1500 R.P.M. was connected to the reduction gear and the latter in turn was connected to a specially designed water brake capable of absorbing this power at 300 revolutions per minute. The tendency of the

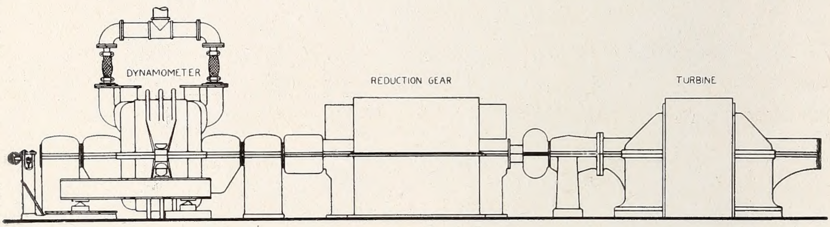


Fig. 7—Diagram showing Arrangement of Turbine, Gear and Brake during Test.

casing of the brake to turn is resisted by a radial arm attached to it and arranged to bear on a platform scale which would weigh the resisting force. This force, the length of the lever arm, and the speed of revolution of the brake rotor being known, the power transmitted may be calculated accurately by the familiar Prony brake formula. It is then only necessary to know the power supplied by the turbine in order to determine the efficiency of the gear in transmitting the power from the turbine to the brake, which in the case of the test was a substitute for the propeller that would ordinarily be driven from the gear shaft.

In order to establish the exact amount of power being transmitted by the turbine to the gear, advantage was taken of a characteristic of the steam turbine in transmitting a perfectly definite amount of power with a given pressure at the steam inlet as long as the speed of the turbine, the pressure in the

exhaust and the quality of the steam remain constant. This fact made it possible to calibrate the turbine used by substituting for the reduction gear a directly coupled brake. Then, by operating the turbine at a fixed speed and by maintaining a constant vacuum in the exhaust outlet, the brake horse-power developed at certain inlet pressures was measured. On plotting a curve of the results obtained with different inlet pressures, a scale was created from which the horse-power corresponding to any inlet pressure could be easily read—as this line is almost straight, the readings between the points representing the actual observations could be determined with very considerable accuracy. The general arrangement of the turbine, gear and brake is shown in Fig. 7; the detail of the brake is given in Figs. 8 and 9. In test-

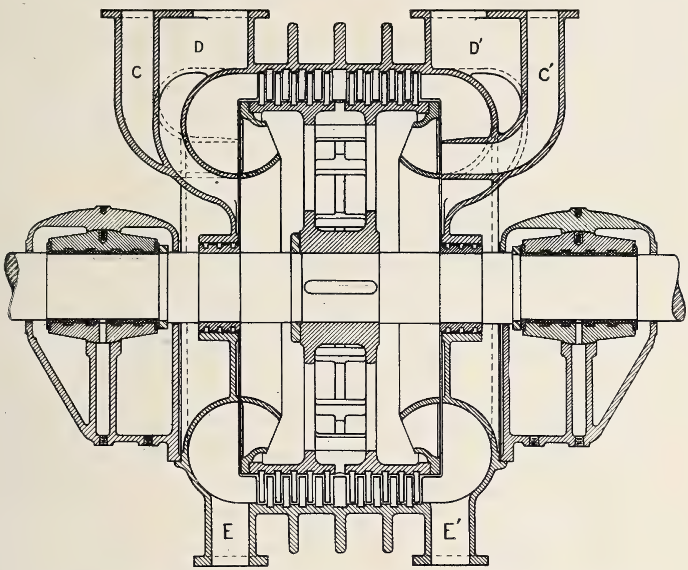


Fig. 8—Section through Brake used in Testing Gear.

ing the turbine the standard high speed brake used at East Pittsburg was employed.

Most careful (and several times repeated) tests demonstrated that the efficiency of the gear exceeds 98½%. As a check on the results so obtained the efficiency was again determined by measuring the quantity of oil circulated in the bearings and in spraying the gear teeth, and by keeping a record of the rise in temperature of the oil, the number of B. T. U.'s lost in friction was calculated.

It was found that the gear would transmit a load of 6000 H.P. at the speeds for which it was designed with only a moderate rise in temperature, and that there was no indication that this was near the limit of load which could be transmitted. The

reason that more load was not applied was that the limit of the capacity of the turbine furnishing the power had been reached.

Having determined the efficiency and the load carrying capacity of this type of gear, the effect of its adoption for marine service incites a great deal of interest. To begin with more efficient turbines may be employed owing to the use of the higher speeds thus made practicable. For instance, careful tests of turbines of approximately the capacity of those of the *Mauretania* and *Lusitania* (when operated at speeds which the reduction gear will make possible for marine work) developed one B. H. P. hour on eleven pounds of steam per hour. On the other hand, while definite information is not available as to the steam consumption of the *Mauretania* and *Lusitania* turbines, it is believed to be at least 14½ lbs. per B. H. P. hour. Besides at the comparatively low speed of the turbines on these vessels, it still exceeds the speed for best propeller efficiency, probably an efficiency of only 55% obtains, while with reduction gear permitting the use of lower speed it is safe to say its efficiency may be made at least 65%. It is understood that the *Lusitania* uses

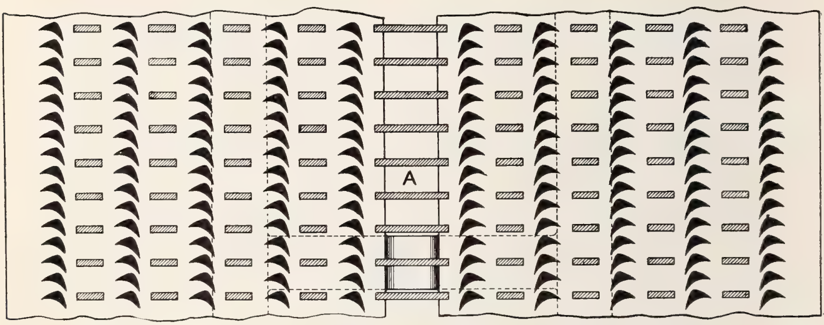


Fig. 9—Diagram showing Arrangement of Blading in Brake.

4700 tons of coal per voyage and the result of increasing the propeller efficiency from 55% to 65% would therefore mean a saving of coal amounting to over 700 tons. In addition, the more efficient high speed turbine would further reduce the coal consumption almost 1000 tons. This aggregates 1700 tons per voyage or a saving in coal alone of over a quarter of a million dollars per year on one ship.

The effect of this increased efficiency of both turbine and propeller in a marine installation has an even farther reaching effect, as a large reduction in coal bunker capacity is also brought about and moreover the boiler H. P. required is reduced about one-third. On the *Lusitania* there are twenty-three double-ended and two single-ended boilers, the double-ended boilers being 17½ ft. in diameter by 22 ft. long, the saving of one-third of the space occupied by these boilers will be seen to be a very large

item. As each of these ships carry 192 firemen and 123 trimmers, the reduction of the number of boilers to be fired would effect a very material reduction in the expense for this part of the crew.

In addition to the saving of space occupied by coal bunkers and boilers, the use of reduction gears will effect a great saving in the space required for the engine room. In the case of the *Mauretania* and the *Lusitania* this would amount to fully one-half of the present requirement.

While no estimate is presented of the increase in earning power due to the greater space for freight made available by the reduction in the size of engine room and space occupied by boilers and coal bunkers, it will be readily appreciated that this will also be a factor to be reckoned with.

There is another consideration which deserves mentioning, viz., if the increased space made available by the reduction in boiler and engine room and bunkers could not be profitably used the general proportions of the vessel might be decreased, which would immediately have an accumulative effect and again reduce the amount of power required for propulsion.

The requirements for warships are very different from those of fast passenger ships which run normally at full speed, as warships run at full speed only in case of emergency. When cruising they use less than one-fourth of full power. As the efficiency of the existing marine turbine rapidly falls off at reduced (rotative) speeds the steam consumption per H.P. hour becomes serious when the ship is running at cruising speed. The desideratum is therefore a turbine capable of performing economically at both cruising and full speed. Realizing the inadequacy of the present marine turbine to fulfill this requirement, Mr. Westinghouse has brought out a design which will give almost as good economy at low speeds as at the higher speeds. This is accomplished by a very ingenious type of valve gear controlling one set of nozzles and blade passages for full speed and an additional set for cruising speed—obviously required for the reason that the velocity "abstracting power" of the blades reduces with the lower peripheral speed, due to the steam leaving the wheel at higher velocity. In the design referred to the steam is redirected upon the blades as often as necessary to efficiently utilize the velocity of the steam.

It has already been pointed out that in the case of the merchant ships a great saving may be effected in the steam consumption and consequently in the cost of coal and the space required for the equipment and coal storage. Now, for the warships not only the same advantage obtains but an additional and very important gain over present practice may be realized by thus increasing the possible cruising radius. This is of inestimable value from a strategic standpoint.

Doubtless many other uses will be found for this reduction

gear, one of which will surely be to drive large D. C. generators with turbines, but if it had no other use than for marine work, it must be looked upon as a very great achievement, and as marking an epoch in the history of marine engineering.

NOTES ON ARCHITECTURE.*

H. F. BALLANTYNE, B.A.Sc., '94

I am asked to say something to you on an architectural topic. To comply with this request I might select some building and describe to you the various problems that presented themselves in planning for its construction and the manner in which they were met; but, this method of procedure is objectionable in that it would leave many of you without any definite idea of what architecture is or what it means, for I take it that only a few of those present have given the subject of architecture serious thought.

In considering still further what I might say to you at this time my mind naturally went back to such experiences as I have had when dealing with engineers in matters architectural, and I was reminded of differences in the point of view from which a building project is regarded by the Architect and the Engineer with the resulting differences of opinion that sometimes exist between them, as to the object to be attained and the best method of attaining it.

Knowing that the Engineering Society is composed chiefly of men preparing for various branches of the engineering profession, I thought I might render both Architectural and Engineering students some service in that while trying to stimulate the interest of the architectural student I might aid the engineering student to some general knowledge of the subject in a way that might be of practical service to him should he engage at any time in the erection of buildings of an architectural character.

The subject of architecture is a large one and we cannot hope to cover it, in even the most superficial manner, at this time; we will therefore confine our attention to an effort to determine what architecture is and illustrate some of its essential features by means of historical examples.

Architecture has to do with building, the subject frequently being divided into Civil architecture, Military architecture and Naval architecture. In what follows, military architecture, the building of forts and fortifications; and naval architecture, the building of ships will not be considered. We will confine our attention to Civil Architecture, which we will understand to include houses, churches, schools and college buildings, libraries, legislative and other buildings of a like nature to these, in which an effort is made to embody the architectural quality.

* Address delivered before general meeting of Engineering Society, February, 1910.

Before going further, let us try to define architecture and so better understand what is meant by architectural quality.

From an examination of numerous hand-books on the History of Architecture one might infer that architecture is somewhat difficult to clearly define. One very eminent authority, Viollet-le-Duc, defines architecture as the "Art of Building." Another, Prof. Fletcher, an English author, defines architecture as "Construction with an artistic motive."

Professor Hamlin, of Columbia University, New York, in his history defines architecture as "The art which seeks to harmonize in a building the requirements of utility and beauty." He further states that the erection of structures devoid of beauty is mere building, a trade, not an art. Edifices in which strength and stability alone are sought and in designing which only utilitarian considerations have been followed, are properly works of engineering. Only when the idea of beauty is added to that of use does a structure take its place among works of architecture.

This last definition is, I think, best for our present purpose. To say that architecture is the "Art of Building" requires further explanation to have much meaning to many of us. That architecture is the art which seeks to harmonize in a building the requirements of utility and beauty conveys the further idea that a building to be architectural must meet or serve the purpose for which it is erected in a direct and practical manner; also that the different divisions or masses of the building must bear such relations to each other both in size and form as will be pleasing, the wall surfaces and roofs, the door, window and other openings must be correctly proportioned and spaced. The materials of construction must be obtainable at reasonable cost, be durable, but not too hard to work, must also have sufficient strength and good surface or texture; each material must be of pleasing color and the different materials of colors that will look well together. Ever keeping before us the fact that the building must be constructed of available materials, by workmen often of only moderate skill, and having made provision for all requirements of utility, the masses, sub-divisions and details must be so related to each other and the construction so refined and perfected that the whole will possess at least some elements of beauty.

It is agreed then, that a building to be classed as architecture must meet both these requirements of utility and beauty. This utility and beauty is obtained in a structure, the product of skill and labor applied to materials provided for us by nature.

All architecture is based on a very few fundamental principles and I wish to devote the greater part of the time that remains in an attempt to show that all essentially good architecture is not the product of the mere fad or fancy of the architect or designer, but is based on fundamental principles which govern and must be followed.

These fundamental principles (*) are structural, are four in number and are commonly designated by the method employed to cover an enclosed space, as follows:

1. Lintel or beam construction.
2. Arch and vault construction.
3. Truss construction.
4. Cohesive construction.

In lintel construction a single cross piece or beam rests on walls, piers or columns, and is subjected to transverse stresses.

In arch and vault construction, several pieces commonly of stone are made to span an opening between two supports. These pieces are in compression and exert lateral thrusts which must be taken up by the massiveness of the abutments or by counter thrust from other arches or vaults.

In truss construction, a frame work is built up with pieces of wood or steel in a form to resist the stresses to which it is subjected, the whole truss forming a compound lintel or beam.

The fourth system of construction, that of cohesion, employs concrete placed when plastic in moulds or forms, which on setting or hardening produces a solid and rigid mass. Concrete itself having little tensile strength, is, when necessary, reinforced with steel rods, bars or wires buried in the concrete, producing reinforced concrete.

Architecture is based on the use of one or more of these four structural principles; which structural principle or system of construction is used, depends in each case upon the materials of construction to be employed.

When large flat stones of considerable tensile strength are available, we find, as in early times, that lintel construction in stone is common. Timber also from a very remote past has been obtainable for beams. At the present time, except for minor work, our lintels or beams are of steel.

Where simple timber or steel beams are not suitable we form them into trusses.

When, as in the not distant past, iron and steel were not obtainable for this purpose and timber was either scarce or avoided on account of its destructibility, stones of moderate size were used in arch and vault construction. When a good cement is obtainable and sand and gravel or broken stone is available, concrete is at our service.

Our main purpose at this time being to show that fundamentally, good architecture is based on good construction, we will omit any reference to detail of forms, mouldings or ornament. We will also pass over any reference to plumbing, heating, electric lighting and other work of a similar nature, which though ordinarily necessary, are in the nature of equipment. Neither will we consider planning except incidentally and in reference to providing points of support.

Let us now examine some examples of the architecture of

* See Hamlin's History of Architecture.

the past and note how the principles of construction already spoken of were employed.

The earliest architecture of which we have any definite knowledge is that of Egypt, and is of the lintel type of construction.

The Egyptians by 6,000 B.C., or 8,000 years ago, had attained a high state of civilization and were well skilled in the arts.

The earliest remains are chiefly tombs, the famous pyramids dating from about 4,000 B. C., themselves being the tombs of the Kings. The grand age of architecture in Egypt is, however, in the time of the New Empire, so called, dating from 1588 to 1150 B.C. During this period the buildings are chiefly temples.

The great temple at Karnak is one example and its plan shows the typical arrangement of an Egyptian temple with its

Fig. 1. Temple at Philae

entrance pylons and surrounding outer wall. We enter a doorway between these pylons into an outer court surrounded by columns; beyond this is a hall or room with many columns and beyond this still other chambers and passageways leading to the inner and most sacred part of the temple.

This particular temple is an enormous structure, its extreme length being 1,215 feet and its greatest width 376 feet; but, the particular part to which I wish to draw your attention is the great Hypostyle Hall, "the noblest single work of Egyptian architecture," which covers an area 340 feet by 170 feet, and contains 134 columns in 16 rows, which support a massive stone roof. Stone lintels are carried across from column to column

and upon these are placed the large stones which form the roof covering. Through the centre of this hall you will also note two rows of columns each 70 feet high and 12 feet in diameter which support a roof at a higher level than the rest. This forms what is known as a clear-storey and shows an attempt on the part of the Egyptians to light this hall in a manner that we shall see was used with good effect at a much later date.

Contemporary with Egypt, and of as great age, was the civilization of Caldaea and Assyria in the Valleys of the Tigris and Euphrates Rivers. Both stone and timber were scarce in these countries and their architecture is only of secondary importance. The Assyrian Empire was succeeded by the Persian in the 6th century B. C. Persian architecture was much influenced by the architecture of Caldaea and Assyria and by that of Egypt as well; but, none of this Asiatic architecture is of much interest to us, beyond the fact that some progress was made in the use of arch and vault construction.

It is to Greece that we must now turn for our examples of lintel construction.

During the time that the Great Temples of which we have spoken were being built in Egypt, the land now known as Greece and also the Coasts of Asia Minor were inhabited by nomadic and sea-faring peoples who traded freely with each other and with the Egyptians and became acquainted with the great architectural monuments of Egypt.

The early Greek architecture is heavy and somewhat rude; but, following the wars with the Persians in the early part of the 5th century B. C. a great period of prosperity ensued and we find great attention paid to art and architecture.

Greek architecture like the Egyptian was of the purely lintel type of construction; but, in plan the Greek temple is very different, for whereas the Egyptian temple was surrounded by a massive stone wall with the columnar construction inside, in the Greek temple an inner chamber is surrounded by a great colonnade which with the light and shade of a southern climate produced a very striking and impressive appearance.

The most perfect examples of Greek architecture and of lintel construction are found upon the Acropolis at Athens and include the Parthenon and the Erechtheum.

The Parthenon was the temple of the Goddess Athena, in plan 102 feet by 228 feet, with two rooms or chambers and a portico at either end, the whole being surrounded by a colonnade, each column about 34 feet high and supporting architrave, frieze and cornice of lintel construction.

The Erechtheum, located near the Parthenon, though very irregular in plan, also shows the use of lintel construction.

The ancient Greek, like the modern Britisher, was a seafaring man and a traveler. He established colonies in many places upon the shores of the Mediterranean, and built many

temples so that the Greek form of lintel construction became familiar throughout that entire region.

The success attained by both Egyptians and Greeks in the use of lintel construction was largely due to the possibility of obtaining stones of very large dimensions. Sandstone and syenite were used by the Egyptians while the famous Pentellic and other marbles were obtainable at Athens and many other places throughout Greece.

But the limitations of this system of construction are shown in the difficulty the Greeks had to provide proper roofs for their buildings. They did not care to fill the interior of their buildings with columns as the Egyptians had done, and resorted to the

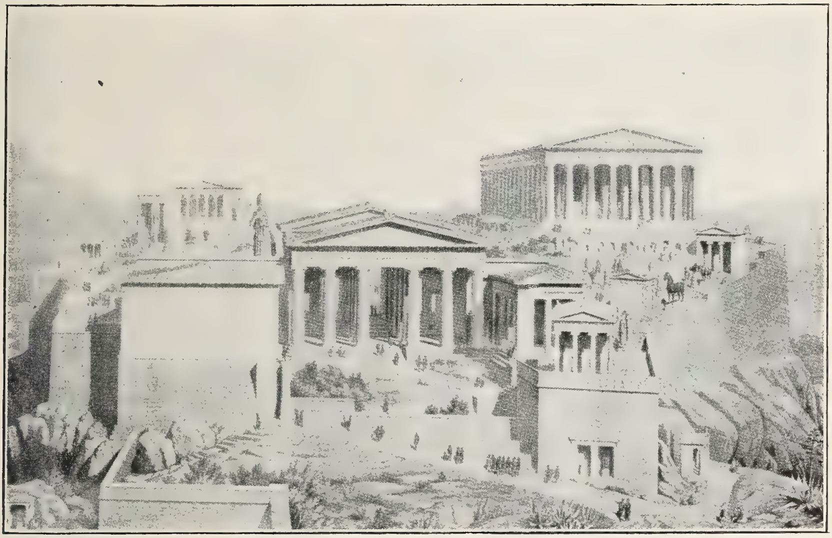


Fig. 2. The Acropolis at Athens

use of timber beams to span wide spaces with the result that the roofs of the Greek temples have long since been in ruins.

For further light on this subject of construction we must turn to the buildings of the Romans.

Before the time of the Romans and during the time when the Greeks were erecting their finest buildings, the central and northern part of Italy was inhabited by a people of prehistoric origin and known as the Etruscans.

The Etruscans had reached an advanced state of civilization, were great engineers and builders and made free use of the arch and vault in their building operations.

Arch and vault construction was known of, at a very early age; the use of the arch also was not unknown to the early Greeks; but with excellent marble to hand, they chose to employ the lintel method of construction and made little use of the arch.

It was otherwise with the Etruscans and their successors, the Romans, and it is to Rome that we must look for the first practical use of the arch and vault, the second system of construction which we are to consider.

The Romans though seemingly lacking in culture were wonderful organizers and administrators. By about 300 B. C. they had overcome the Etruscans and other kindred peoples and became the masters of Italy. In 146 B. C. Greece was made a Roman province.

The Etruscans were engineers and builders and the Greeks artists. The practical Romans, as administrators and men of affairs, directed the efforts of these engineers and artists to evolve from the architecture of their predecessors a mighty architecture adapted to new and novel conditions. They constructed buildings suited to a great variety of new requirements and made the arch and vault the basis of their system of construction. They systematized their methods of construction so that soldiers and barbarians could erect the rougher parts of their buildings while the decorative details were standardized and simplified so that workmen of moderate skill could execute them. The Romans, too, were expert planners and displayed their genius in the great variety of arrangement and plan of their buildings, always keeping in mind the requirements of construction, convenience and artistic effect.

Such was the character and genius of this people who were to take up the science and art of building when the Greeks had carried lintel or beam construction to its greatest perfection.

We have noted the difficulty which the Greeks had with the roofs of their temples. Let us now examine the Roman method of meeting this difficulty.

In the Basilica of Constantine erected at Rome in 312 A. D. we have an advanced example ot Roman vault construction.

Basilicas were erected by the Romans as halls of justice and as exchanges for merchants, and comprise some of the finest buildings erected by them.

In the Basilica of Constantine we find a somewhat elaborate system of vaulting. The side compartments are covered with barrel vaults placed at right angles to the main axis of the building and the central portion or nave is covered with intersecting barrel vaults forming at their intersections what are called groins; these vaults are therefore called groined vaults.

In one of the halls of the Baths of Diocletian we have another example of Roman groined vaulting.

These examples and many others which we cannot mention show the ingenuity of the Romans as constructors. In Italy and in the provinces it was often difficult to obtain large stones, the time consumed woud also be considerable. By the use of arches and vaults, smaller stones could be used, even the lintel forms being built up of small stones and supported on masonry arches.

It will be observed that the Roman vaults were semi-cylindrical in section, either the simple barrel vault or the groined vault being used to cover corridors and oblong halls.

At the time the Basilica of Constantine was erected, 312 A. D., conditions were preparing for a change; Christianity had developed great power. The Emperor Constantine himself professed Christianity and the Christians who up to this time had been an unpopular religious sect, were now able to hold their services openly and freely.

In 324 A. D. Constantine removed his capitol from Rome to Byzantine which hereafter is called Constantinople.

The architecture developed at Constantinople is known as the Byzantine style. We cannot discuss this style further than

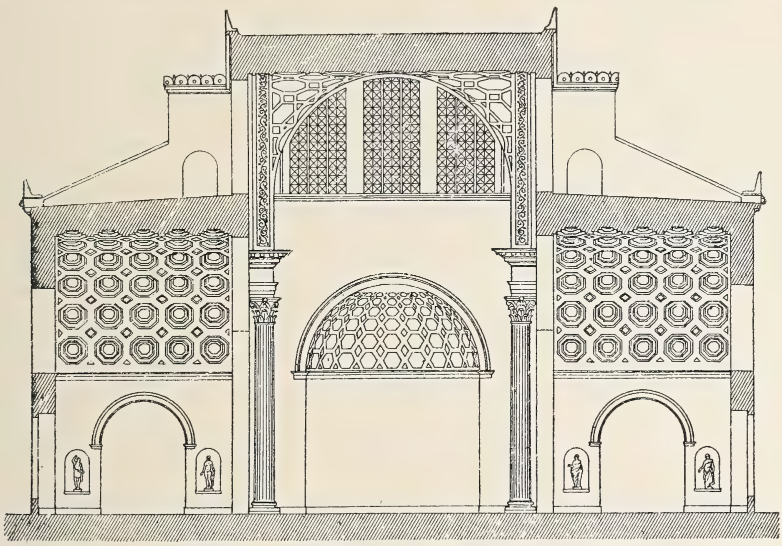


Fig. 3. The Basilica of Constantine

to state that domes instead of vaults were used to cover their buildings; this system of construction, a modified form of vault construction was the forerunner of the modern dome of which the dome of St. Peter's at Rome, the dome of St. Paul's Cathedral in London and still more recently, the dome of the Capitol at Washington are examples.

In Rome and other places in Italy and Western Europe the early Christians adopted the plan of the Roman Basilica for their churches, but without the vaulted roofs.

From the early part of the fourth century Christianity, through the Church of Rome, became the great promoter of civilization and the arts of Western Europe, and it is to churches and monastic buildings that we must look for progress in the art of building.

Though the Western Roman Empire came to an end in the latter part of the fifth century A.D., the buildings of the Romans continued to be the models for those constructed for several centuries afterwards. For almost five centuries, however, the progress of architecture in Western Europe was very slow and it is not until the tenth and eleventh centuries that this new architecture of Western Europe, and known as Romanesque, becomes of great importance.

In the 10th and 11th centuries conditions had so improved that we find the priests and monks in Italy and Western Europe trying to build churches of stone in which the general plan of the Roman Basilica appears in simpler and more massive form and so far as possible of fireproof construction.

Numbers of these buildings were erected in Southern France where Roman remains are numerous.

Two well-known examples of Romanesque vaulting of a late date and of an advanced type are also found in Northern Italy in the churches of San Ambrogio at Milan and San Michele at Pavia.

In these, as in earlier examples, the nave is divided into square bays by transverse arches and the space between is covered with groined vaults. Between the large main piers in these examples, however, are smaller piers with arches in two storeys carrying a wall above, which in turn supports the roof.

The great difficulty with all this vaulted construction is to take care of the thrust of the vaults and this may have been one reason why the Greeks did not use this form of construction.

Amongst the Romans, in some cases, by sheer mass of masonry in the side walls they resisted this thrust which in a barrel vault is distributed equally along the entire length of the side walls; in others by internal buttresses or pilasters and the assistance of an outer wall or colonnade they secured stability. In still others, as in the Basilica of Constantine, they concentrated the thrusts at definite points and by building cross vaults at right angles thereto, the thrusts at these points are taken up.

The Romanesque builders also struggled with this problem of thrusts, with more or less success, when the centre was not carried up into a clear-storey. The need of the clear-storey, however, increased their troubles and many of the early structures with clear-storeys fell down.

Two remarkable churches in which vaults with clear-storeys were successfully constructed, are situated at Caen in Normandy, France. These are the Church of St. Etienne (Abbaye Aux Hommes) and the Church of La Trinité (Abbaye Aux Dames) built for William the Conqueror, in 1066 A. D., the same year in which he crossed over into England.

The plan of St. Etienne shows the nave divided into square bays with the side aisles sub-divided in a manner very similar

to that employed in the Churches of San Ambrogio and San Michele. Here, however, the large vaulting bays are divided across the middle by arches which divide the vaults, each into six parts, producing what is known as the six part vault. The vaults in general are semi-circular in section and the windows round-headed.

In these churches the thrusts of the vaults are concentrated at double the number of points possible with the square vault and by means of small external buttresses and internal bracing the thrust of these vaults has been resisted now for almost 900 years.

These churches at Caen, in style, are the Norman version of the Romanesque, sometimes called Norman Romanesque or simply Norman, and are the immediate predecessors in point of time of the Norman architecture of England, of which numerous examples still exist.

The expedient of the six part vault as found in these churches of Normandy, though in use for over 100 years, was not satisfactory; the masonry was still heavy, the windows small and the lighting poor; the form of the six part vault also is awkward.

The problem before the architects and builders was therefore to devise a better method of vaulting, one in which less masonry was required both for economy and to obtain more window space, a method by which the thrust of the vaults could be taken up and at the same time produce vaults of more artistic and pleasing appearance.

These conditions were finally met in a very ingenious and logical manner in Central and Northern France, between the years 1150 and 1500 A. D.

The Frenchman of that time, as now, was an ingenious and daring individual and very logical. He, by employing two principles, which had been made use of in a limited way by the Roman and Byzantine builders, solved the problem.

The first of these principles was the concentration of the thrusts of the vaults upon isolated points of support by means of groined instead of barrel vaults, in a manner similar to that employed in the Basilica of Constantine. By this concentration of thrusts upon isolated points it was possible to support the vaults upon piers. The walls between the piers or buttresses, became a mere filling which was often in great part replaced by immense windows filled with stained glass.

Having concentrated the thrusts of the vaults upon isolated points, it was necessary to take up the thrusts at these points. This was accomplished by building half arches over the side aisles to buttresses in the outer walls; by this means the thrusts were generally brought sufficiently low to ensure stability, if not, additional weight was added to the buttresses in the form of pinnacles. This combination of the half-arch and buttress is called the flying buttress and "is the one absolutely novel and distinctive feature of this style which is known as Gothic."

These two principles, the concentration of the thrusts of the vaults upon isolated points of support, and the taking up of these thrusts by flying buttresses formed the structural basis of the Gothic styles, but their application lead to the introduction of two other principles of almost equal importance. These are ribbed vaulting and the pointed arch.

The difficulty of building centering for intersecting barrel or groined vaults was considerable. If the intersecting vaults are of the same height and semi-cylindrical in section, the inter-

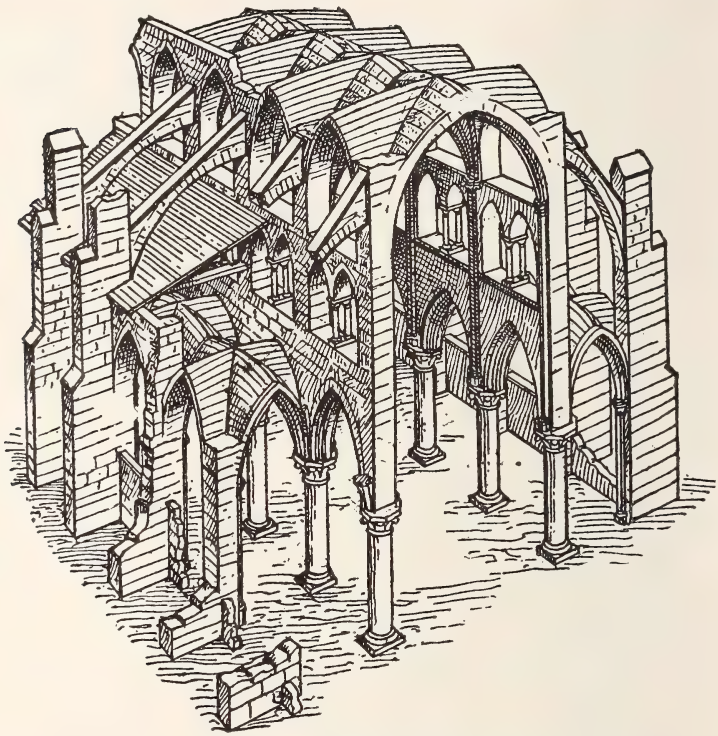


Fig. 4. Gothic Construction

sections or groins lie in vertical planes and are elliptical in section. Under these conditions the Romanesque architects conceived the idea of constructing these intersections first, forming skeleton vaults with ribs of stone; the spaces between these ribs were then filled in with comparative ease, the ribs helping to support the centerings for each of the four or more compartments of a vaulting bay.

But it was not always possible to keep the vaulting bays square as is required if semi-cylindrical vaults are to intersect in vertical planes. To remedy this difficulty when the vaulting bays were oblong instead of square the pointed arch was adopted.

By this expedient vaults of varying widths could be brought to the same height; the diagonal ribs were commonly made semicircular with the intersecting vaults more or less pointed.

The spaces between the ribs are slightly warped surfaces; but, this was not so great that it could not be taken care of in the construction of the separate compartments of the vault.

The pointed arch was thus introduced as the most convenient form for the construction of the vaulting ribs and was soon applied to other parts of the structure from necessity, as where it is necessary to make window openings fit the spaces between the vaults, or from a desire for uniformity in the style of the openings.

This entire system of vaulting, constituted the inner roof or stone ceiling of the building, generally a church or a cathedral, and was covered over with a timber roof to protect it from the weather.

This Gothic style, the architecture of the flying buttress and the pointed arch was the sequel or outgrowth of the Romanesque styles which had preceded it and these Romanesque styles in turn were founded upon Roman models.

Vault construction with its problems of thrust and counter thrust as met with by the Romans was thus developed by slow stages during the Romanesque period and was worked out and reached its final solution in the magnificent Gothic cathedrals of the 13th and 14th centuries in Western Europe.

Thus far we have confined our attention to buildings embodying the structural principles of the lintel and the arch or vault, and have tried to show, that of all buildings constructed in which the lintel system of construction was employed, the architecture of the Greeks was the highest development, the Parthenon on the Acropolis at Athens built in the 5th century B. C., having been the most perfect example.

Following the Greeks we found the Romans, about the beginning of the Christian era, incorporating the principle of the arch and vault with that of the lintel. The architecture of the arch and vault after a long period of evolution reached its final and logical conclusion in the Gothic architecture of North Central France in the 13th and 14th centuries. Of this Gothic style, the cathedrals at Amiens and Rheims and that of Notre Dame in Paris are examples.

Further, in our discussion of lintel and vault construction we have dealt with structures of masonry. Our illustrations have been temples, basilicas, cathedrals, buildings of an imposing and monumental character. Even in some of these, the lintels, as for example the supports for the roofs of the Greek temples, were probably of timber. Many of the English cathedrals and churches, were not vaulted and even when vaulted, the vaulting had to be protected by timber roofs. The use of timber brings us to a consideration of our third system of construction, that of the truss.

Timber was undoubtedly used from a very early age, but

wood being of a perishable nature, ancient examples of its use are not in existence and our knowledge of how it was employed is therefore meagre.

Carvings on Egyptian monuments show tombs evidently designed to imitate wooden models and the Egyptians, doubtless, lived in houses constructed of wood.

In Western Asia, along the shores of the Mediterranean Sea, lived the Phonecians and others, builders of ships and skilled in the use of wood; their rock cut tombs are constructed after models in wood. The Greeks, too, were a sea-faring people. They, therefore, were also builders of ships and skilled in timber construction. Wood, doubtless, was used freely in their less important structures. When we come to the Romans, though no examples of their work in wood remain; we know that they were well skilled in working with timber and in carpentry.

But it is the timber construction of the late Romanesque and Gothic periods of the 12th and 13th centuries and later that most interests us for of this many examples are still to be found in Northern France, in England and in Germany.

The timber construction of the Middle Ages was based on Roman models, the material employed being heavy squared timbers of oak, a wood which was plentiful in Northern Europe at that time.

Timber construction was used in conjunction with masonry or alone. All of the cathedrals, as has been said, even when vaulted in stone, were covered with wooden roofs. In the castles and other secondary buildings, the floors were of wood supported on heavy beams, while the roof construction was of timber supported on wooden trusses.

In minor buildings, such as houses and shops, the entire structure above the foundation, was framed up in timber, and in the Middle Ages, the towns of Northern France, England and Germany were filled with buildings of so-called half-timber construction in which the spaces between the beams were filled with masonry or plaster.

The timbers were framed with mortise and tenon, the joints being fitted together with great precision and secured with oak piers; spikes and bolts were never used.

The most interesting examples of timber framing in the Middle Ages are shown in the construction of the roofs.

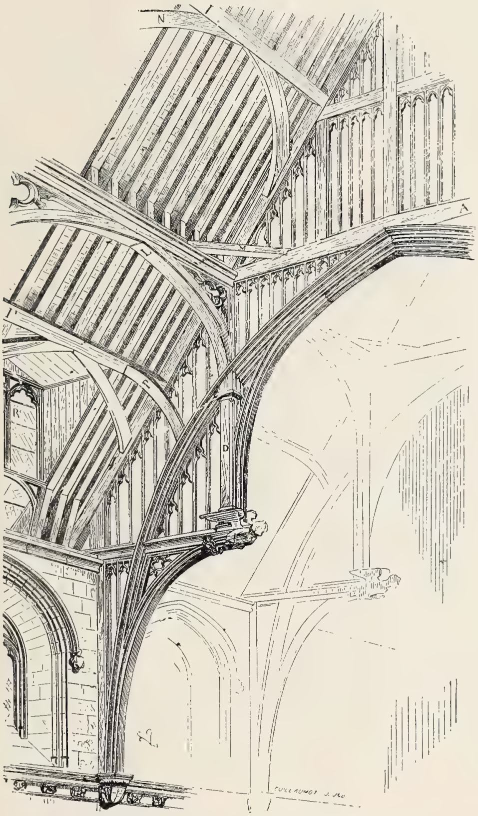
Roofs are of two kinds; in the one the timber framing is exposed on the inside and in the other it is hidden from view by some form of ceiling. In this latter case little attention need be paid to appearances, the aim being a strong and economical construction; with exposed trusses and roof timbers it was otherwise; here care was required in both form and construction to secure both strength and pleasing appearance.

Though somewhat timid in the use of stone vault construction the English were very successful in building timber roofs. Probably the finest timber roof in existence, is that of West-

minster Hall, London, with its series of hammer beam trusses built in the reign of Richard II.

Trusses of timber were used almost exclusively down to the latter part of the 19th century when the introduction of wrought iron and steel brought about a change. Now, except for minor buildings, our trusses, and even the frames of some of our buildings, are of steel.

Our fourth principle of construction, that of cohesion of



No. 5. Hammer Beam Truss

materials, has to do chiefly with the use of concrete, in this later day reinforced with metal when required to take up tensile stresses which this material is not well suited to resist.

The use of concrete is both a very old and a very new art. It was employed by the Romans 2,000 years ago and by ourselves chiefly within the last 20 years. The Romans found the materials for a good hydraulic cement ready to hand; while, we, having learned to make good Portland cement from lime and

clay, can obtain a good cement in large quantities in almost any place and at moderate cost.

The Romans were provided with a much greater variety of building materials than the Greeks. In Greece, the chief and almost the only building material was marble. In Italy, marble, terra cotta, stone and brick were largely used; besides these, lava and pozzolana, the products of volcanic eruptions, and excellent sand and gravel were plentiful. It is with these latter materials that we are now most interested.

Pozzolana is a clean sandy earth which when mixed with lime produces a good hydraulic cement, and this cement mixed with small or broken stones, pieces of bricks or other debris produced the concrete of the Romans.

Roman concrete so-called is in general of two kinds; in the

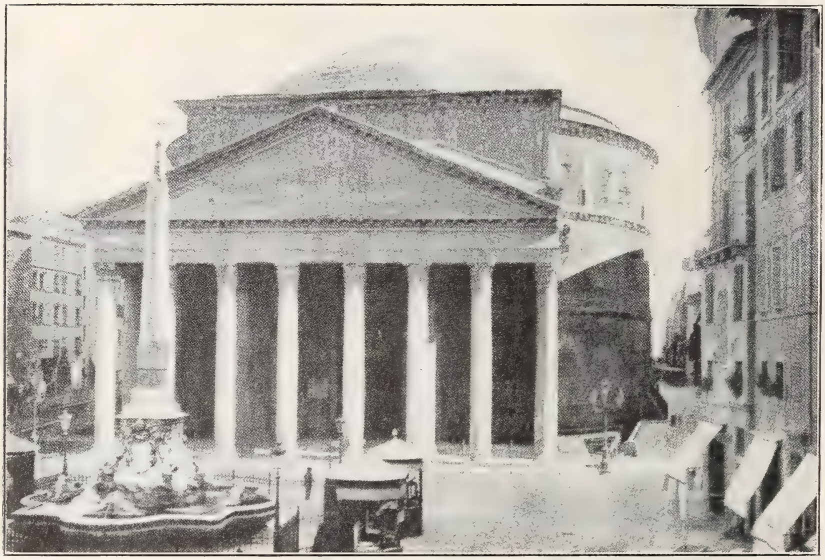


Fig. 6. The Pantheon at Rome

one the materials are mixed much in the manner of modern times; in the other small sized stones were placed in a heavy bed of fresh mortar in the wall and pressed down into it. In either case the resulting mass is much the same.

One of the most celebrated buildings of antiquity, the Pantheon at Rome, is of this latter form of construction. The Pantheon is circular in plan, 142 feet internal diameter and the same in height with walls 20 feet thick. The roof is in the form of an inverted saucer, with an opening at the top 27 feet in diameter by means of which this vast interior is lighted.

In construction this dome, brick or tile ribs with cross ties were built on comparatively slight centerings of timber and this

system of brick ribs formed the support for the concrete placed upon it; thick and heavy at the haunches and lighter towards the top.

Other Roman buildings, as the Basilica of Constantine, the Baths of Caracalla and of Diocletian had vaults of concrete or massive masonry in which the cohesion of the cementing material greatly reduced the thrusts upon the supporting walls.

This Roman manner of using concrete depended on being able to obtain materials for a natural hydraulic cement. These materials were plentiful in various parts of Italy but not common elsewhere. As a result little use was made of concrete construction outside of Italy until recent times when from certain stones it was found possible to make hydraulic limes and cements. Still more recently, with the advancement of science and with improved appliances, excellent Portland cements are made in many sections of this and other countries.

Cement and reinforced concrete construction is now common and we are all more or less familiar in a general way with the manner in which it is employed. Architecturally there are still several difficulties encountered in the use of concrete; buildings being more or less irregular in outline it is difficult to make the forms required. There is also the further difficulty of obtaining pleasing surfaces on the exposed walls. Whether a house made of concrete is sufficiently free from dampness is still another question.

On the whole the employment of concrete for buildings is still in its early stages, its use being confined chiefly to footings, foundations and floors.

For bridge abutments, retaining walls and other places where the forms are simple, and appearance and dryness of secondary importance, concrete gives excellent results. But concrete is a coming material and with more experience on the part of the architect in designing to suit the material and also with more experience and skill on the part of the man who handles it, in time, doubtless concrete will be freely used in constructing buildings of real artistic merit.

In what has been said this far, I have tried to define architecture, and to enunciate and illustrate its fundamental principles.

Architecture has been defined as the art of building in such a way as to meet the requirements of utility and beauty, and we have seen to a limited extent how these requirements are met; we have further seen that the underlying fundamental principles are structural and have examined illustrations of historic buildings embodying these principles.

During the time that I have been speaking of these various historic buildings, many of them very ancient, I doubt not some of my hearers have been wondering why it seemed necessary to examine these older buildings to the apparent neglect of others more modern and up-to-date.

From one point of view my supposed critics are correct, for

unless we can make some practical use of our knowledge of the architecture of the past, it is well nigh useless.

Let me try to explain.

In describing the properties of electricity, it is not uncommon to compare it with the flow of water in pipes. In much the same way, and for the same purpose, architecture is likened to language.

Each language has its own peculiar structural form with its own idioms and vocabulary; if we speak the English language correctly, we must construe our sentences in accordance with its established principles, and use its idioms and the words that belong to its vocabulary in accordance with their accepted meanings.

If, on the other hand, we speak another language, as for example German, we employ a language of different construction and with other idioms and another vocabulary.

To speak the English or any other language in a manner acceptable to educated persons, we must conform with its structural principles, obey the established rules, and use the forms of speech which have gained the approval of those best qualified to judge.

If we do otherwise, we fail to express ourselves clearly, and show ourselves uneducated. If we employ words not sanctioned by good usage, we are guilty of using slang.

With architecture we have shown that each historic style is based on the use of a definite structural principle, and if we had gone further, we would have found that certain structural forms, mouldings and other details are identified with each style, and that certain kinds of ornament and decoration are most appropriate to it.

These architectural styles are used by architects as the basis of their designs.

Again, some one may object, and ask why employ any particular architectural style, why employ forms, details and ornament of more or less ancient origin, why not be original and devise new forms and new methods of your own?

Apply the same criticism to the English language. Refuse to use the language in accordance with its recognized structural forms; refuse to employ its idioms and its vocabulary, and try to invent new forms of expression and new words, and what is the result? An unintelligible collection of words and no words that have little or no meaning to the person who hears them, and which convey but an indefinite and hazy expression of the ideas of the person who uttered them.

On the other hand, if we employ the language in accordance with the best usage and with accuracy, and use its vocabulary correctly, and as is indicated in a good standard dictionary, we may convey to the minds of our friends the best thoughts of which we are capable with great accuracy, in the form of simple prose, or in a more imaginative and poetical form if our minds

are so ordered. The great power and beauty of both thought and expression of which the language is capable is shown in the poems of a Wordsworth, a Browning, or a Tennyson.

We have outlined the possibilities of literary composition; so, too in architectural composition, by complying with the underlying requirements of good construction in a given style and by the use of a vocabulary of forms, details, and ornament appropriate to the style, derived, it may be, from older forms but adapted to modern requirements in the same way that a language is, we may produce modern buildings adapted to all the modern utilitarian requirements and at the same time full of neaning and interest to those capable of understanding them, and of a very high degree of beauty and artistic excellence, if the designer, like the poet, is capable of producing them.

THE ONTARIO BOARD OF HEALTH EXPERIMENTAL PLANT.

F. H. CHESNUT, B.A.Sc., '07
Engineer in Charge

At the present time when so much is being said, and justly, regarding the conservation of the vast natural resources of this country and province, the question of Public Health should not be entirely lost sight of. Surely the good health of our citizens is one of the greatest, if not the greatest, resource with which this fair country has been blessed. It must be admitted, even by the most shallow thinkers, that a country populated by a healthy race, not only tends to be better morally and spiritually, but will undoubtedly be the better able to develop those many natural resources which the Creator has placed at its disposal.

The question then arises, have we not in Canada ideal conditions for promoting health; if so, why worry over such questions as Public Health? The question is very pertinent. Yes, we have almost ideal conditions, or rather the close observer would say, we *had* ideal conditions and in some places these conditions have improved and in others they have deteriorated.

The next question is, what are these improper conditions, and what is their origin? The answer is, carelessness or ignorance have brought about unsanitary conditions of living. In explanation of this statement probably a short sketch of the rising of a nation would not be out of place, and would apply in general to our country as well as to any other.

The tribe or embrio nation divided itself into villages, each village disposing of its household wastes in a pit or oftentimes on the surface of the ground. When conditions became too bad and the senses of the inhabitants became tortured to the extreme the whole village packed up and moved to a new camp. This nomadic life soon became impossible, due to the increase of

population. As soon as permanent villages became the only possible way of living we find records of terrible plagues which exterminated whole countrysides, and as the population of the country became denser and great manufactories were established the streams and lakes became so foully contaminated as to be nothing more than open sewers, and the nation became shaken to its core by epidemics of water-borne diseases.

The reader will readily see that the foregoing is nothing more than the life history of England up to about the year 1800.

Well, but you say, we have no such conditions in this country. No, but our present generation will see such conditions unless there is a concerted move in the direction of cleaner waterways and more regard on the part of the individual citizen, for the good health of his fellow being. What town in Ontario hesitates to dump its sewage and factory wastes into the nearest stream or river without even taking the trouble to find whether the town a mile or so down stream is going to be injured or not? There are few who hesitate, for to hesitate would mean ruin from the financial standpoint, so they say. Is this justice, that one town should be required to purify the sewage of another? You will say, and rightly, that the up stream town may dispose of its sewage in such a way as to not in any way affect the lower town; but that the people of this latter town would not feel safe in drinking the unpurified stream water on accocunt of contaminating features along its flow, which they or anyone else would be powerless to prevent. The evident answer is this: it costs much less to purify comparatively pure water than water directly contaminated by sewage, also from the esthetic point of view the nuisance caused by sewage is not to be desired.

To my certain knowledge a number of such conditions already exist in this province and still the health authorities are powerless to prevent their existence. And why are the health authorities powerless? Because the laws which govern sanitary conditions are inadequate and antiquated and the enforcing of such laws as do exist is in no way supported by public sentiment. But where do such laws originate? In the legislature, you say. Not at all. The people make the laws, and if the people make the laws it is the business, yes the duty, of every citizen, who realizes that better sanitary conditions are to be desired and can be had, to help to educate his neighbor to better ideals.

Surely prevention is better than cure. It is said that one Eastern nation pays its doctors so much per annum to keep its people well. When one gets sick the doctor's salary stops forthwith. Could we not follow this example by paying our sanitarians to keep us well?

What we want is better and purer water supplies. Pure water is one of the most essential things to human existence. Every community is willing to pay a small amount more per gallon for pure milk; but how many of these same communities

are willing to add .0005 cents per gallon or .05 cents to their per capita daily supply of water, and get in return the cheapest and most useful commodity we have?

Let us assume then, that pure water is to be desired. How may it be obtained? By a consideration of the following general requirements:

(a) Look to the source of supply. If it be a lake or river which is liable to contamination due to sewage from towns in the district, either obtain a new and better source of supply or remove the cause of pollution, if not entirely at least so that the dilution which the sewage or waste receives is sufficient to make direct pollution of the water supply infrequent or remote.

(b) Having removed all apparent sources of pollution, the question should not then be considered completely solved, for even the best inspected water supplies show pollution at times.

(c) Finally, in a word, obtain the best possible water supply and purify it by the best known method.

The Ontario Government has seen fit to establish and maintain an experimental plant at Stanley Park in this city, with the following objects in view:

(1) The education of the general public to a more enlightened view of the questions of sanitation, in particular with regard to pure water supplies.

(2) The graphic demonstration to the general public of the possibilities in the different well-established processes of water purification and sewage disposal.

(3) The endeavor to discover new methods of water purification and sewage disposal, or to improve existing methods.

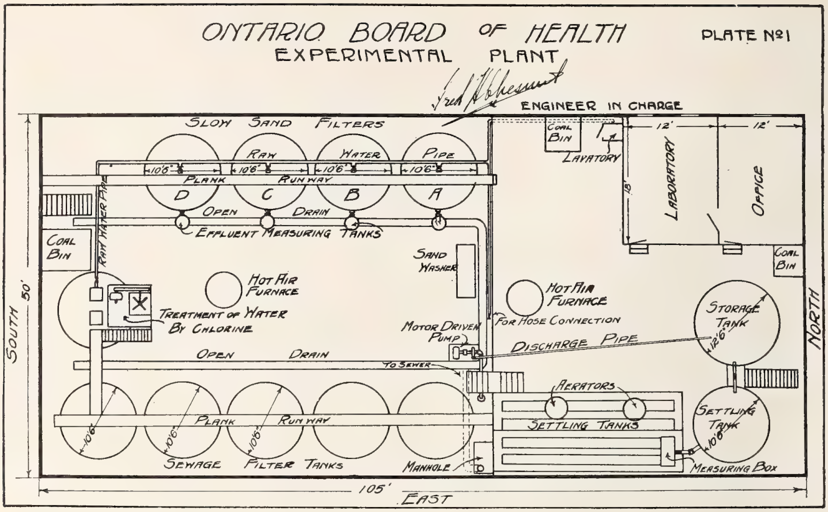
Description of Plant.

The plant is situated at the northern extremity of Stanley Park on Clifford Street. The building (105′ x 50′) is constructed of a timber framework covered with corrugated iron and lined inside with building paper. The main floor, on which are situated the tanks (see Plate 1) is some eight feet below the level of the ground outside, while the remainder of the floor space is at ground level. At the northwest corner are situated the office and laboratory. The work done is divided into two main divisions—Water Purification and Sewage Disposal.

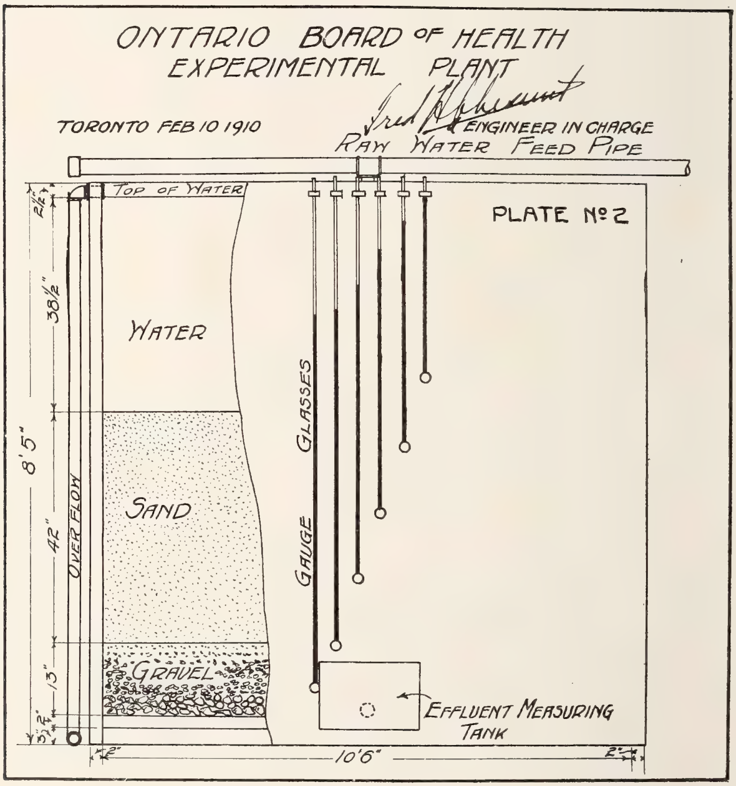
Water Purification.

(a) *Slow Sand Filters.*

On the west side are seen the four slow sand filters for the filtration of raw or city tap water. Each of these tanks (see Plate 2) is circular and of the wooden stave type, eight feet high and ten feet six inches in diameter, having a surface filtering area of one five-hundredth acre. In each tank is placed 13 inches of gravel graded from 6-inch stones at the bottom to very fine material where it comes in contact with the sand. Over this is placed 3½ feet of sand having an effective size of .265 milli-



ONTARIO BOARD OF HEALTH
EXPERIMENTAL PLANT
PLATE No 1
ENGINEER IN CHARGE
SLOW SAND FILTERS
RAW WATER PIPE
PLANK RUNWAY
D C B A
OPEN DRAIN
EFFLUENT MEASURING TANKS
COAL BIN
RAW WATER PIPE
HOT AIR FURNACE
TREATMENT OF WATER BY CHLORINE
SAND WASHER
MOTOR DRIVEN PUMP
FOR HOSE CONNECTION
DISCHARGE PIPE
TO SEWER
LAVATORY
LABORATORY
OFFICE
STORAGE TANK
AERATORS
SETTLING TANKS
SETTLING TANK
MEASURING BOX
MANHOLE
SEWAGE FILTER TANKS
SOUTH 50'
NORTH
105'
EAST



ONTARIO BOARD OF HEALTH
EXPERIMENTAL PLANT
TORONTO FEB 10 1910
ENGINEER IN CHARGE
RAW WATER FEED PIPE
TOP OF WATER
PLATE No 2
WATER
SAND
GRAVEL
OVER FLOW
GAUGE GLASSES
EFFLUENT MEASURING TANK
8'5"
38½"
42"
13"
10'6"

meters and a uniformity coefficient of 2.056, the whole of this sand and gravel being carefully washed before being placed in the tank. The graded gravel is used as a support to the sand, keeping it from being washed out with the effluent. Each tank is provided with loss of head gauges, which consist of metal tubes running horizontally and radially from the centre to the sides of the tank and terminating on the outside and at right angles in glass tubes. These are placed at different levels and therefore the loss of head for several depths may be noted; the difference between each successive reading being the loss of head due to the friction of the sand in the vertical distance between the gauges. The discharge from each tank is measured in a measuring box, which contains several orifices, each of

Slow Sand Filters

which under a fixed head gives a fixed and known discharge.

In operating the filters the raw water (city water) is run on the bed and in most cases allowed to stand for an hour. The effluent valve is then opened sufficiently to give the required discharge. As is well known, a "blanket" begins to form on the filtering surface at once, consisting of the suspended matters removed from the water as it passes through. It is this blanket which does the greatest part of the work in filtering. However, each grain of sand below the surface becomes coated with a jelly-like substance to which bacteria and other suspended matters readily cling. The exact amount of purification which takes place below the surface is unknown, but it is believed to be sufficient to warrant the placing of 3½ feet of sand instead of

a few inches, which would be sufficient if the whole of the purification took place on the surface.

The first object aimed at in the operation of these slow sand filters was to obtain data which would establish the best rate at which Toronto or Lake Ontario water may be filtered, having in mind minimum cost of plant and cost of operation and maximum efficiency from a biological standpoint.

With this in view the tanks designated *A, B, C* and *D* were started on September 15th, 1909, at the following rates: Tank *A,* 20,000,000 gals. per acre per day. Tank *B,* 15,000,000 gals. per acre per day. Tank *C,* 10,000,000 gals. per acre per day. Tank *D,* 5,000,000 gals. per acre per day.

While the tanks have been run a sufficient length of time to give a fair idea of what the final results will be, it has not

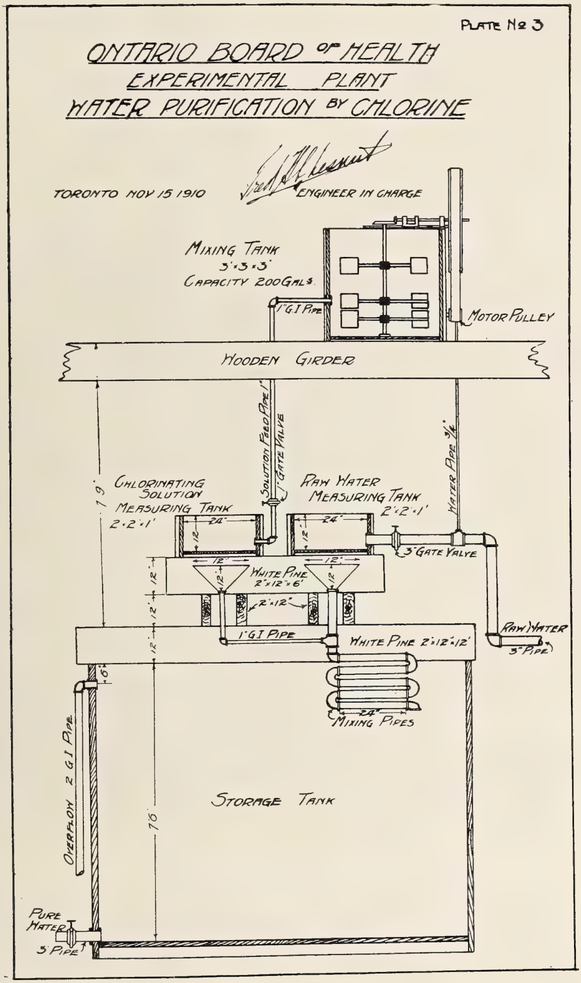
Water Purification by Chlorine

been thought advisable to make any statement in this regard as only a broad knowledge of what slow sand filters will do for Lake Ontario water can be reached by averages based on considerable data regarding "length of run," "discharge during run," "bacterial efficiency," etc. It may be said, however, without fear of correction, that slow sand filters will give the citizens of any town using Lake Ontario water, a good water, both from esthetic and biological standpoints.

(b) *Water Purification by Chlorine.*

Dr. J. W. Leal, of Boonton, N.J., has installed a plant at that town which purifies the total water supply (40 million

gallons per day) of Jersey City by the addition of small quantities of "bleach" to the raw water, without previous filtration of any kind. This treatment gave in many instances a sterile water and at all times a reasonably pure water (i.e., comparable

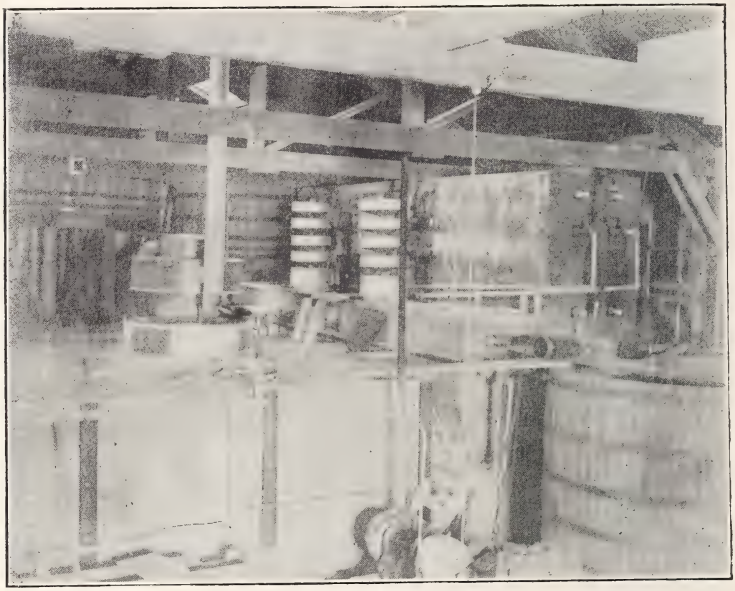


with slow sand filter effluents) and at the cost of 14 cents per million gallons.

With the object of attempting to repeat this performance a plant of this nature has been constructed and has just been put in operation at the Experimental Plant.

From Plate No. 3 the general layout may be seen. The raw water enters the Raw Water Measuring Tank through a 3-inch pipe where the quantity flowing per hour is measured by

means of a sliding orifice equipped with a graduated operating screw. Chloride of lime ("bleach") is mixed with a definite per centage (by weight) of water in the Mixing Tank, which is kept constantly stirred by a mixing device operated by a motor. The solution of chloride of lime then flows to the Chlorinating Solution Measuring Tank through a one-inch pipe and is there measured by the same method as the raw water. The chlorinating solution is added in such proportions so that a definite quantity of "available chlorine" is added to a definite quantity of water, both by weight. As will be seen the raw water and the chlorinating solution are caught in funnels and come together at the two inch to one inch tee connection. They are then well mixed in the system of return bend piping and fall into the tank



Sewage Disposal Equipment

below, where different storages may be given depending on the flow of raw water and on the height of the adjustable overflow.

It is to be expected that there may be some difficulty in treating raw water by this method, due to the high turbidities frequently found. However, a roughing filter or a mechanical filter can readily be installed and used to give preliminary treatment before being "finished" by the chlorine process.

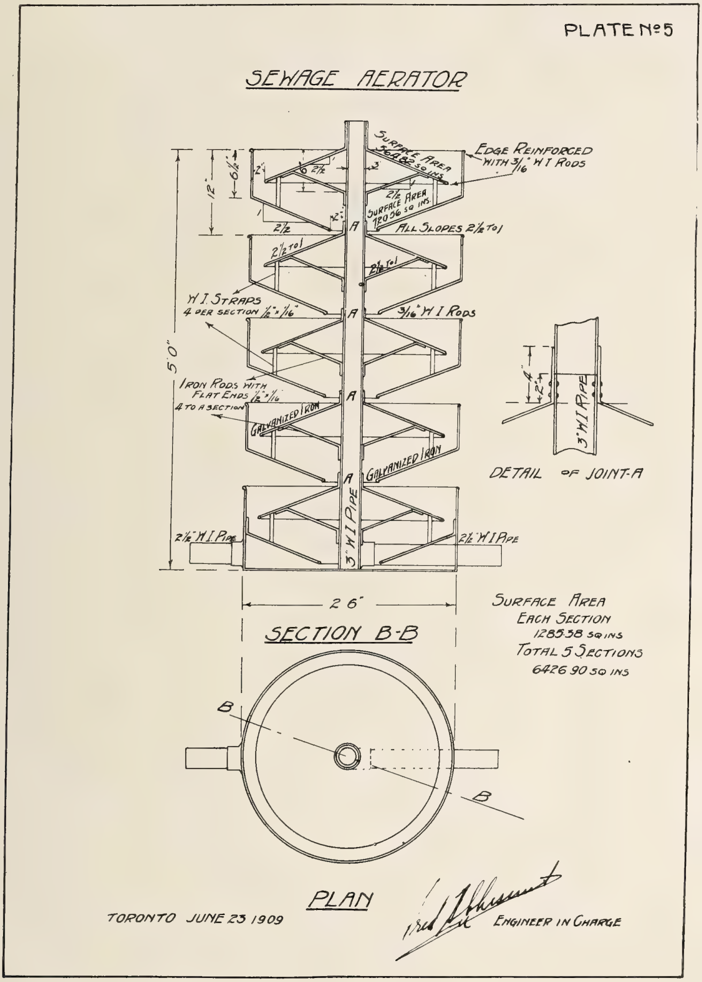
Full results of the operation of this plant will be published later.

Sewage Disposal

Owing to the unfortunate circumstance of a poor pumping installation it has been found impossible to raise the sewage

from the 7½ foot sewer which runs under the building. The construction of a new manhole has just been completed and it is hoped that a plentiful supply of sewage will be obtained at an early date.

The fact of having no sewage has prevented the operation of such plant and apparatus as we have at present in position,



and the possible prospect of a limited supply of sewage has prevented extensive planning of future work.

As will be seen from Plate No. 1, the sewage is lifted by an electrically driven centrifugal pump, of 150 gallons per minute capacity, some 40 feet from the Garrison Creek sewer to a storage tank which is equipped with a float apparatus which

throws out the motor when the level of the sewage in the tank reaches a certain required height.

The storage tank is connected to a settling tank by a 2½-inch pipe. From this settling tank the sewage is led into a measuring box, which rests on the top of the concrete settling tanks No. 1A and No. 1B. This measuring tank is equipped with brass orifices which are of such a size as to discharge sufficient quantities of sewage to give different rates of storage in the settling tanks, thus for one hour storage an orifice is used which discharges 1665 U. S. gallons per hour, which is the capacity of the concrete settling tanks used.

The sewage having been measured as described it is subject to protracted settling action for different periods of time and to aeration in aerators of the form shown in Plate 5.

The object of the layout just described is to determine the best rates at which settling tanks may be run, with aeration or without. The effluents from these tanks will be for the present run into the sewer, but later will be treated by the several different methods of filtration or to disinfection or sterilization.

The visible accomplishments which the plant shows, at the present time, are not in any way a measure of the time, labor and thought which has been expended on it. It is believed that the future will justify, in the concrete form of valuable data obtained, the money invested in this undertaking. We have done our best in an attempt to accomplish the objects aimed at and it is hoped that the citizens of Ontario will show more interest in the work which is being done by visiting the Experimental Plant and becoming acquainted with our work.

REINFORCED CONCRETE COLUMNS.

PETER GILLESPIE, B.A.Sc.
Lecturer in Applied Mechanics

The exact function performed by steel reinforcement in concrete columns, whether in the form of longitudinals or as hoops or spirals, has been the subject of much speculation and investigation. The behavior of the composite material under stress has not been and is not now satisfactorily understood. Do the steel and the concrete deform together in accordance with the classical assumption to that effect? Are there initial stresses in the metal (and also therefore in the concrete) due to a tendency to contract while setting? Does the presence of the steel affect significantly or at all, the elastic properties of the concrete which immediately surrounds it? Is the use of reinforcing metal, either as longitudinals or as hoops, an efficient and economical method of strengthening compression members? These and other questions that might be asked have been for theorists, an excuse for evasive hypotheses, and for investigators, a stimulus to investigation. In the discussion of efficiency and economy, a knowledge of the elastic and other properties of the materials employed is of prime importance. An ability to interpret the geometrical features of the stress-strain curve is a part of this knowledge, and is therefore very essential.

In Figure 1, the stress-strain curves for two concrete prisms are shown, the data having been obtained from "Tests of Metals" for 1904. The upper curve is for a 1:1 cement and sand mortar of ultimate crushing strength, 6,940 lbs. per sq. in. The lower is for a 1:2:4 cement, sand and gravel mixture which failed at 1,700 lbs. per sq. in. It will be observed that while the former continues straight, up to a stress of 2,500 lbs. per sq. in., the latter deflects almost from the start. That the former is at the outset, almost twice as steep as the latter will be interpreted as meaning that the modulus of elasticity of the richer concrete is nearly twice as great as that of the poorer. That there would be a permanent "set" for relatively small stresses in the case of the latter would be anticipated. As might also be expected, a much closer approach to complete recovery was realized in the other instance after even moderately large stresses.

When two dissimilar materials deform together, it is usually assumed that they take stresses in proportion to their relative rigidities. If, for example, the steel in the longitudinal reinforcing of concrete columns be ten times as rigid as the surrounding concrete, its stress for a given deformation will be ten times that of the concrete. Experiments conducted on columns of concrete of the grade ordinarily manufactured and reinforced in this manner show that the stresses in the steel, accompanying stresses in concrete of such intensity as is commonly specified, are very much lower than good practice will endorse or economy

recommend. In the accompanying table are given some data taken from Tests of Metals for 1904. In parallel columns are shown simultaneous values of stress in concrete and in steel longitudinals in compression members having from .97 to 2.09 per cent. of reinforcing.

Simultaneous Stresses in Concrete and Steel.

Mixture—variable.
Percentage of metal in longitudinals—.97 to 2.09.

Test No.	Mixture	Average Stress, lbs. per sq. in.	Steel Stress, lbs. per sq. in.	Concrete Stress, lbs. per sq. in.	Steel Stress. / Concrete Stress.	Ultimate Strength, lbs. per sq. in.
1613	1:1:2	600	3,540	556	6.4	2,890
1612	1:2:3	600	6,360	516	12.3	2,010
1582	1:2:4	600	5,040	557	9.0	2,180
1581	1:2:4	600	5,520	549	10.1	1,990
1584	1:2:4	600	4,320	527	8.2	2,830
1579	1:2:4	600	3,780	532	7.1	2,760
1610	1:2:4	600	5,220	532	9.8	1,820
1616	1:2:4	600	9,060	476	19.0	2,095
1608	1:3:6	600	11,100	446	24.9	1,370
1617	1:3:6	600	4,860	516	9.4	2,290
Average			6,000	530	11.6	

From this table, it is seen that the average stress existing in steel longitudinals in columns carrying 600 lbs. per sq. in. over the gross area was only 6,000 lbs. per sq. in. In structural and bridge work, working stresses at least twice this would not be considered excessive. It is undoubtedly true that metal is sometimes employed in structures for emergency purposes, and ordinarily may sustain stresses which are very small indeed, or absent altogether. In the case of concrete columns, this is partly true. To take care of bending stresses due to eccentric loading, or to possible inequalities in the concrete, longitudinal rods are necessary; still if the working stresses in them could be increased somewhat past the limit given in the above table, it could be felt that more of the advantages of the use of the metal were being realized, particularly since, even when stressed to the maximum which good practice favors, it carries a load in compression at about twice the cost of concrete.

By employing a better grade of concrete, thus permitting the utilization of higher working stresses, a partial remedy is secured. An improvement in quality is, however, accompanied by a marked increase in the elastic modulus as well as in the ultimate strength as is indicated in Figs. 1 and 2, the latter being a typical stress graph for a plain 1:1 concrete of age three months, plotted from a test made by the writer. The aggregate was a hard trap rock, with the fine crusher dust screened out, the size of aggregate varying from ¼ to ¾ in. The member

was first stressed up to 2,200 pounds per square inch when the load was released. The magnitude of the "set" is almost insignificant, it being observed that the second curve is plotted from a new origin. The prolonged straightness of the curve is one of its most noticeable features. The increase in stiffness which

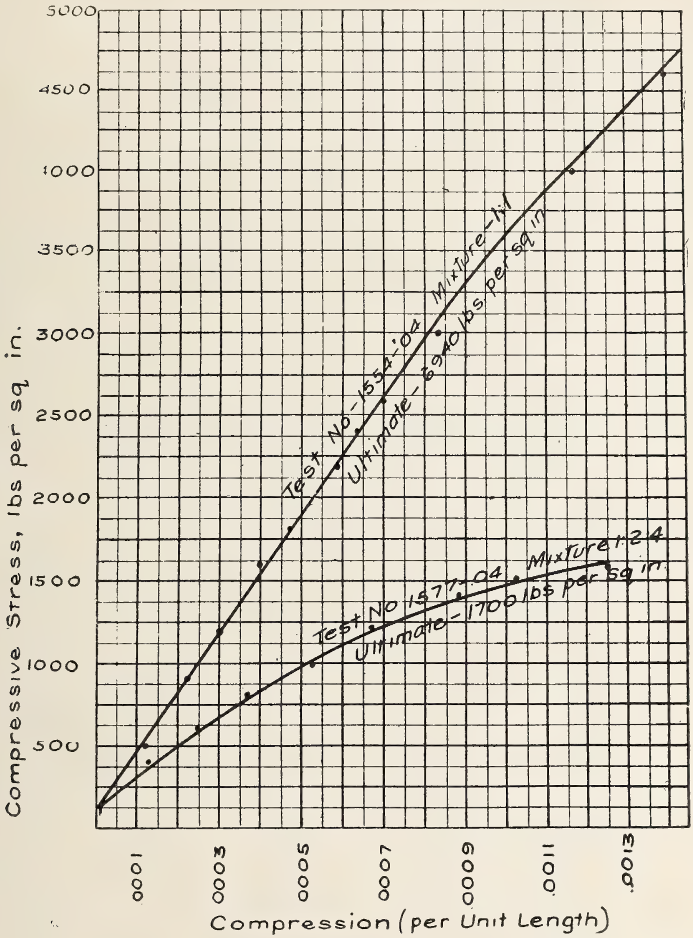


Fig. 1.—Curve showing the behavior of typical rich and lean mixtures under compressive stress

occurs whenever the quality of the concrete is improved, will mean a reduction in the stiffness ratio for the two materials, so that the increase in the steel stress due to the employment of a richer mixture, is not as great as might at first be supposed.

Below are given the results of a few compression tests made

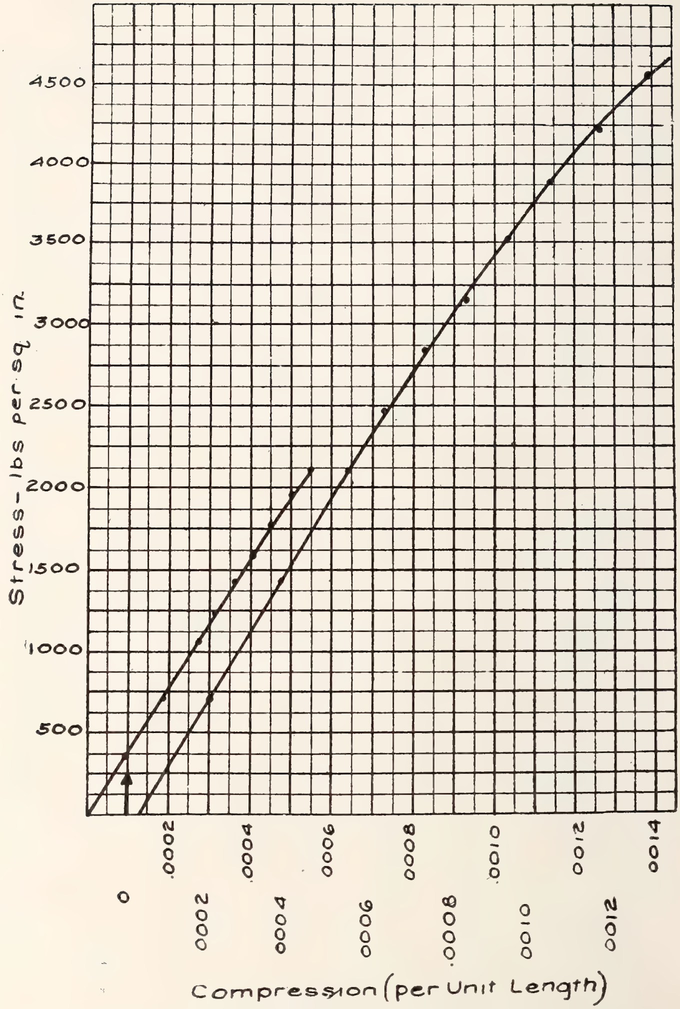


Fig. 2.—Curve showing the behavior of a 1:1 plain concrete under compressive stress

by the writer on columns of this grade of concrete. The specimens were 6 inches in diameter and 21 inches long.

Compression Tests on Short Columns.

Mixture—1:1.

Age—6 months.

Specimen No.	Crushing Strength, lbs. per sq. in.
A	4,900
B	5,975
C	5,150
D	6,160
E	4,120
F	5,480
Average—	5,300

As the average strength is well over 5,000 lbs. per sq. in., it would seem that a working stress of 1,250 lbs. per sq. in, is not excessive.

To determine the manner in which such material will behave

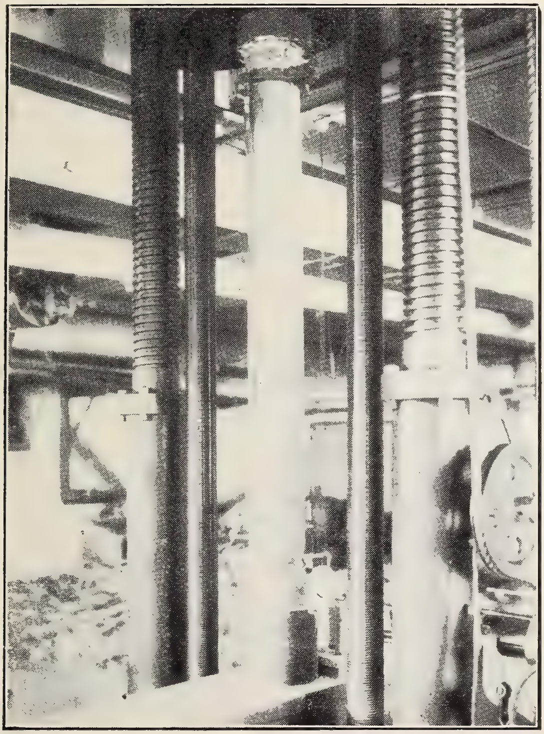


Fig. 3—Column with longitudinal reinforcement under test

in combination with steel, longitudinally placed, a number of columns were constructed and tested. Nine determinations of the modulus of elasticity for this concrete plain, gave an average value of 3,900,000 lbs. per sq. in., with the smallest value 4 per cent. lower, and the largest 4½ per cent. higher than the mean of all. Eight determinations of the elastic modulus in columns, reinforced with from .88 per cent. to 4.42 per cent. of steel, gave an average value of 3,600,000 lbs. per sq. in., showing that apparently the concrete is less rigid in the reinforced column than it is in the plain. In the latter case, the smallest value was 13 per cent. less, and the greatest, 11 per cent. more than the mean of all. The subjoined table shows in a few representative cases, the magnitude of the stress in the longitudinal reinforcement accompanying a stress of 1,250 lbs. per sq. in. in the concrete.

Simultaneous Stresses in Concrete and Steel Longitudinals.

Mixture—1:1.

Percentage of metal—.88 to 4.42.

Designation.	Stress in Concrete, lbs. per sq. in.	Stress in Steel, lbs. per sq. in.	$\frac{\text{Steel Stress.}}{\text{Concrete Stress.}}$
M	1,250	9,300	7.4
J	1,250	9,600	7.7
H	1,250	10,500	8.4
N	1,250	10,500	8.4
Q	1,250	12,000	9.6
R	1,250	10,800	8.6
O	1,250	10,500	8.4
P	1,250	10,500	8.4
Average—	1,250	10,400	8.4

On account of the increased working stress in the concrete, the average stress in the steel is substantially greater. The attainment of such stresses, rendered possible through the employment of a better grade of concrete, must be considered a step toward the economical use of steel in concrete columns.

Another matter of some consequence is the amount of "set" taken by the concrete after the stress is relieved. The most satisfactory materials for the purpose of the engineer are those which have for moderate stresses, the power of perfect recovery. Of concrete, as ordinarily manufactured, this can scarcely be said. It will be observed in the table below, that the average "set" for the rich concrete after a stress of 2,000 lbs. per sq. in. is approximately half as great as that of the poorer grade after a stress of half the magnitude. The data was taken somewhat at random from the report of the Watertown Arsenal for 1904,

but is believed to be fairly representative of the two grades of material.

Table Showing the Amount of "Set" after the Release of Stresses in Two Grades of Concrete. Specimens all 12 Inches Long.

After 2,000 lbs. per sq. in.			After 1,000 lbs. per. sq. in.		
Mixture.	"Set", ins.	Ult. Strength, lbs. per sq. in.	Mixture.	"Set", ins.	Ult. Strength, lbs. per sq. in.
1 : 1	.0006	6,940	1 : 2 : 4	.0028	1,210
1 : 1	.0013	4,800	1 : 2 4	.0020	1,700
1 : 1	.0014	4,360	1 : 2 : 4	.0010	1,480
1 : 1	.0004	6,400	1 : 2 : 3	.0012	1,680
Average	.0009			.0017	

The function of hoops in compression numbers is to resist the lateral expansion which accompanies longitudinal compression due to load. For most materials, there is a more or less constant ratio between the lateral and the longitudinal strain. This is known ordinarily as Poisson's ratio, and for most materials of construction is about 1/3 or 1/4. Let us assume a concrete column reinforced with hoops and with longitudinal rods. When it is stressed by loading, a longitudinal shortening takes place which sets up stresses in both steel and concrete, the ratio between them being the ratio of their relative rigidities. If the hoops were absent, a lateral expansion would have taken place which, per unit of diameter, would be only a fraction of the aforementioned shortening per unit of length. The hoops reduce this to some extent (otherwise they would not serve their purpose), and consequently the unit deformation in them must be of even smaller extent. From this it is manifest that hoop stress will be very much less than the compressive stress carried at the same time by the longitudinal rods, and if some misgivings are had as to the wisdom of employing longitudinal steel in columns, certainly greater doubt might be entertained regarding the use of hoops. For while the fabrication of hooped reinforcement is usually more expensive than where longitudinal rods are used, the safeguard against bending due to eccentric loads and defective materials locally, is very inadequately afforded.

In the hooped columns, the tests on which are referred to below, a 1:1 mixture of small size trap rock and cement was used. The hoops were welded from steel flats and were of two thicknesses, .05 and .12 inches. The quantity of metal relative to the core within the hoops varied from .024 to .057. No longitudinal metal was employed save three strips of thin hoop iron that were employed as spacers for the hoops. In order to

measure the stresses in the hoops, certain of the rings were left exposed, partly or completely, and to these, mirror extensometers were attached. Longitudinal deformations were measured by means of compressometers fixed to a gauge length of about 50 inches. In the curves of Figs. 4 and 5 an opportunity to see the manner in which the steel stress varies with the compressive stress in the concrete is afforded. In every case, as the concrete was subjected to higher compressive stresses, a tendency on the part of the curve to deflect downward manifested itself. In some cases, the curve became parallel with the axis of steel stress. This would indicate that the concrete under high compressive

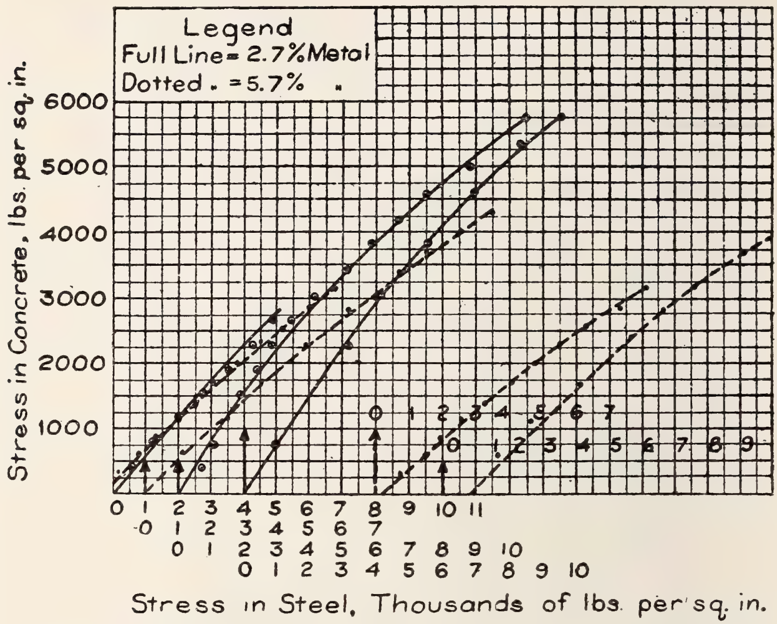


Fig. 4.—Curve showing the ratio of steel stress to axial compressive stress in hooped concrete, mixture 1:1.

stresses, had reached a stage of partial plasticity within the hoops. The fact that on release of load after heavy stressing, the extensometers did not usually completely recover, would indicate that this apparent tendency to flow had left the steel in a state of residual tension, since usually the steel stress had not even approached the elastic limit. In Fig. 5, the continued increase in steel stress under a constant load is shown.

From purely theoretical considerations if the elastic properties of the materials and the quantity of hooping present are known, it is possible to establish a simple relation between the compressive stress in the concrete and the accompanying stress

in the encircling bands. In the evolution of the equation which follows, the stiffness ratio for this material was assumed to be 9. A number of determinations of Poisson's ratio gave ¼ for an

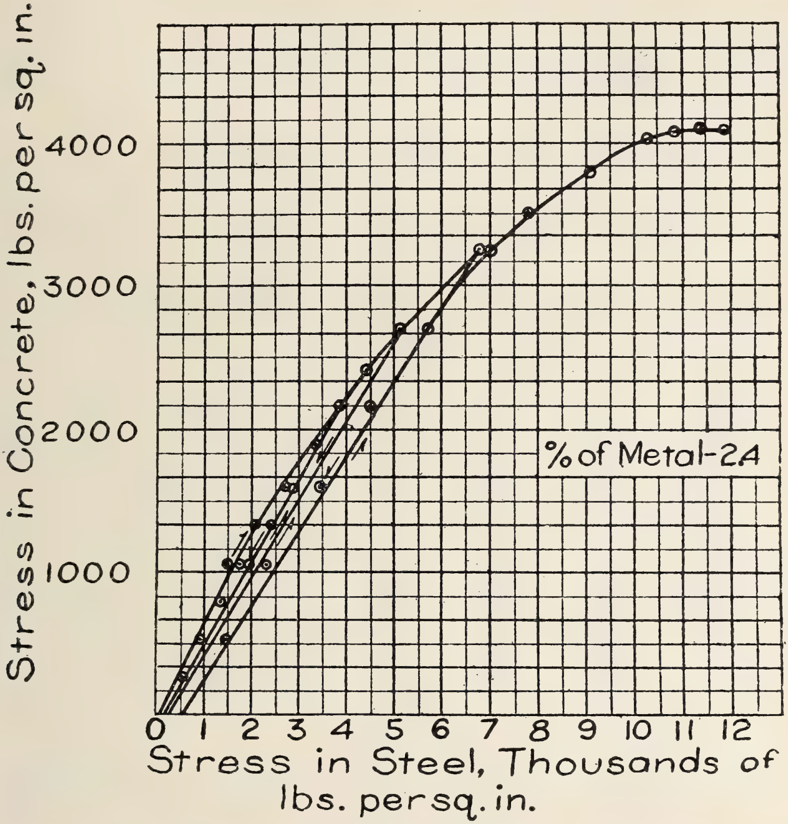


Fig. 5.—Curve showing the behavior of 1:1 hooped concrete repeated compressive stresses.

average value. For these materials, it can be shown that $\frac{f_s}{f_c} = \frac{9}{4 + \frac{9}{2}p}$ where f_s is stress in steel bands, f_c is axial compressive stress in the concrete and p is the ratio of metal to concrete within the bands. Since p is usually small with respect to the other numbers involved, it follows that the usual changes which p might undergo do not affect the ratio $\frac{f_s}{f_c}$ in a very conspicuous way. In Fig. 6, the manner in which this ratio changes consequent on variation of p is shown. The points plotted

adjacent to the curve show to what extent the theoretic investigation agrees with the results of experiment. In the following table are given a few simultaneous values of hoop stress and compressive stress in concrete. The figures are representative of a somewhat large number of determinations and broadly speaking, show, as is indicated on Figs. 4, 5 and 6, that for the materials employed, the hoop stress is approximately twice that in the concrete.

Simultaneous Stresses in Concrete and Steel Hoops.

Mixture—1 :1.

Percentage of metal in hoops—2.4 to 5.7.

Concrete Stresses, lbs. per sq. in.	Hoop Stresses, lbs. per sq. in.	p.	$\frac{\text{Steel Stresses.}}{\text{Concrete Stresses.}}$	State of hoop.
2,400	5,500	.057	2.28	Partially exposed.
3,000	7,000	.024	2.30	Completely exposed.
1,900	4,300	.057	2.26	Partially exposed.
2,300	5,000	.057	2.18	Partially exposed.
2,000	4,700	.057	2.34	Partially exposed.
3,000	6,000	.057	2.00	Partially exposed.
3,250	4,000	.057	1.23	Completely exposed.
2,600	5,000	.024	1.92	Partially exposed.
2,300	5,000	.027	2.17	Partially exposed.
2,800	5,000	.024	1.77	Completely exposed.
2,750	5,000	.027	1.82	Completely exposed.
Average—			2.02	

Tests made by Professor Talbot in 1907 on hooped concrete columns using a 1 :2 :4 mixture showed that the ultimate strength was increased about 570 lbs. per sq. in. for each per cent. of hooping employed. Similarly, tests made at the Watertown Arsenal in 1906 show that one per cent. of metal in the form of hoops increased the strength of the member to the extent of 1,020 lbs. per sq. in. Professor Withey, in 1909, reported that for each per cent. of metal employed in the form of spiral reinforcing, the increase in ultimate strength on an average was 1,320 lbs. per sq. in. for 1 :2 :4 concrete. In most cases, the strength of the columns tested by the writer exceeded the capacity of the testing machine employed. In one instance, where the column had 2.4 per cent. of steel in the form of hoops, the ultimate strength was 7,660 pds. per sq. in. This, it will be observed, is equivalent to an increase in strength over plain concrete of 1,000 pds. per sq. in. for each per cent. of metal. The manner of failure is shown in Fig. 8. From these and other tests which might be cited, a generous allowance for hooping

would be 1,000 lbs. per sq. in. gross strength for each per cent. of metal employed. Tests conducted on hooped columns reinforced also with longitudinal rods indicate that greater efficiency is obtained from the rods than when employed without the hoops.

A comparison of costs between the rich mixture concrete column, carrying light longitudinal reinforcement, and a hooped

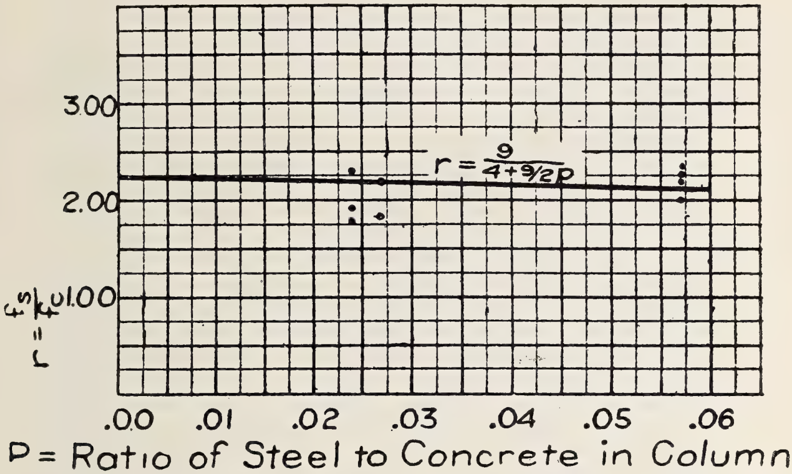


Fig. 6.—Curve showing the theoretic variation of the ratio $\frac{f_s}{f_c}$ with change in the percentage of metal in concrete of mixture 1:1.

structure of estimated equivalent ultimate strength is interesting. The materials laid down have been assumed to cost as follows:

Cement, $1.50 per barrel.
Aggregate, $2 per cubic yard.
Sand, $1 per cubic yard.
Plain reinforcing, 3c. per lb.
Hooping, fabricated, 5½c. per lb.

For a 1:1 cement and rock mixture, the cost per cubic yard will be:

Cement	$ 8.10
Rock	1.58
Labor	2.00
Plain steel, ½ per cent.	2.03
Total	$13.71

Since the metal is added chiefly as emergency material, it

will not be figured in the ultimate strength which will be taken at 5,000 lbs. per sq. in. A 1:2:4 concrete (the ultimate strength of which plain may be assumed at 2,000 lbs. per sq. in.) will be rendered equivalent in strength to the 1:1 mixture by the use

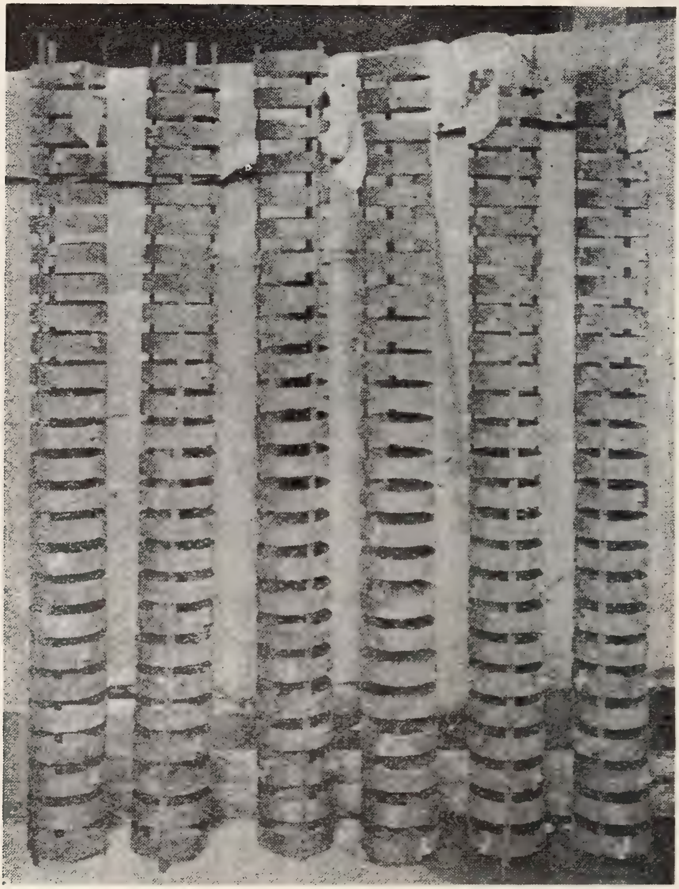


Fig. 7.—Hoop Reinforcement ready to place in forms

of 3 per cent. of hooping metal. The cost per cubic yard will then be:

Cement	$ 2.53
Rock	2.00
Sand	.50
Steel hoops	22.28
Labor	2.00
Total	$29.31

In addition to the greater cost, this column will not possess the stiffness and probably not the margin of safety against bending stresses which are found in the cheaper column.

In order to compare the areas of three different types of columns, and their cost per foot of length, it will be assumed that a 10-storey building with dead and live floor loads at 200 lbs. per sq. foot, and a roof load of 100 lbs. per sq. foot is to be constructed. Assume also square floor bays of 15-ft. to a side.

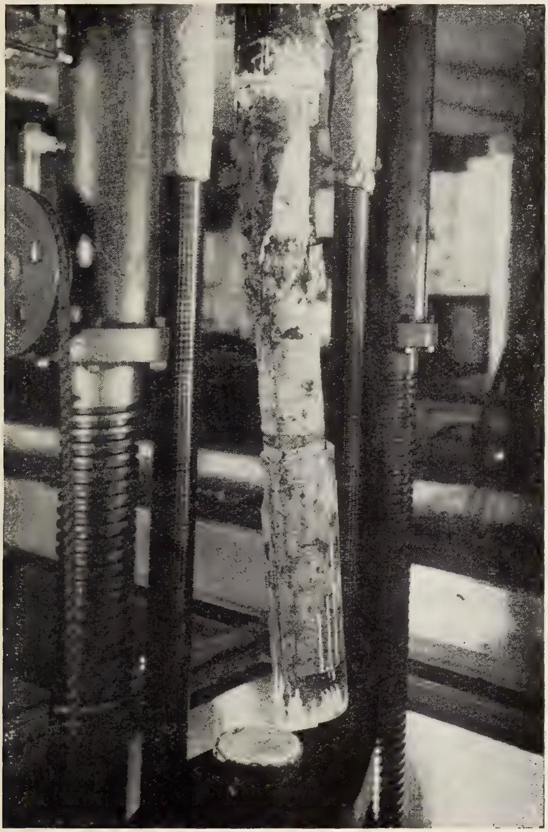


Fig. 8.—Failure of a hooped concrete column; three of the hoops nearest the centre have burst.

It will be seen that the load sustained by a column on the ground floor will be 427,500 lbs. This may be carried:

(a) By a structural steel column.

(b) By a column of the poorer grade of concrete.

(c) By a column of the richer mixture.

A reference to the Carnegie handbook, p. 141, shows that a steel column consisting of two 10-in. channels and two ⅞-in.

plates will be adequate. This column weighs 121 lbs. per running foot. The cost per foot of height will be:

Steel at 5c. per lb.	$6.05
Fireproofing, 2-in. thick	.58
Total	$6.63

A 1:2:4 concrete column with 1 per cent. of longitudinal metal will be figured at 450 lbs. per sq. in. for the concrete, and $450 \times 15 = 6{,}750$ lbs. per sq. in. for the steel. The average stress will, therefore, be $450 (1 + .14) = 513$ lbs. per sq. in. The gross area required will be $427{,}500 \div 513 = 833$ sq. inches. Hence a column 29 inches square will be adequate. Allowing one inch additional for fireproofing, we have a column 30 inches square, the cost of which, per foot of height, would be:

Concrete, including 1 per cent. steel and labor..	$2.55
Forms	.46
Total	$3.01

The third method employs a 1:1 mixture, the working stress on which will be taken as 1,250 lbs. per sq. in. The area required will be $427{,}500 \div 1{,}250 = 342$ sq. inches. This is the area of a square of 18.5 inches to the side. Allowing 1½ inches for fireproofing, we obtain a column 20 inches square, the cost of which per foot of height with ½ per cent. of longitudinal steel would be:

Concrete, including ½ per cent. of steel and labor	$1.30
Forms	.32
Total	$1.62

The areas of the cross-sections in the three cases are:
(a) 1.8 sq. ft.
(b) 6.3 sq. ft.
(c) 2.8 sq. ft.

It is thus seen that the difference between the smallest cross-section and the largest is 4.5 sq. ft., an item of considerable importance in districts where the rental of floor space is high. On the other hand, the difference in cross-sectional area between the most expensive method of carrying the load, and the cheapest is 1.0 sq. ft. Having regard then to the fact that the rich mixture column costs only one-fourth as much as the steel structure, there would seem to be a good deal to be said in favor of the stronger mixture.

The writer desires to state that of the experimental work referred to above, part was conducted in the Testing Laboratory of McGill University in Montreal, and part in the Laboratory of Applied Mechanics in the University of Toronto, the former being done under the general supervision of Professor E. Brown, of the Department of Civil Engineering.

The consideration of the reader is invited to the following

inferences to which an examination of the data at hand seems to lead. Since the experimental evidence supporting these conclusions is, in the opinion of the writer, scarcely extensive enough upon which to base broad generalizations, they are not advanced as being final and conclusive.

1. The rich mixture is more uniform in its elastic properties than the lean mixture, and for proportionate stresses, the permanent set is likely to be very much less. The parabolic feature of the stress-strain curve is also less noticeable.

2. The employment of a rich mixture in columns permits of the more economic stressing of the steel longitudinals. It is very probable that a strength equal to that obtained by the use of a 1:1 mixture can be secured by the careful grading of the aggregate, and the use of less cement.

3. The experiments cited indicate that, for the materials employed, the stress in the steel hoops was approximately twice the axial compressive stress in the concrete core. The steel is consequently not economically employed.

4. Theoretically and experimentally, the variation in the relation of steel stress to axial compressive stress does not vary greatly with variation in the percentage of metal.

5. A given ultimate strength can be more cheaply secured by a rich mixture lightly reinforced by longitudinals than by the utilization of hooping. The former also secures greater rigidity and safety against bending.

6. For equal safe loads on columns, the lean mixture is probably intermediate in cost between the steel column and the rich mixture lightly reinforced by longitudinals, the latter being the cheapest.

7. The cross-sectional area of the steel column is least for a given loading, and the lean mixture greatest. The difference between the cross-sectional areas of a steel fireproofed column and a rich mixture concrete column is the least of all.

BUILDING ACOUSTICS.

G. R. ANDERSON, M.A.

It is a rather remarkable fact that notwithstanding the paramount importance of good acoustics in a public building, there should be a very large proportion of our halls and churches whose acoustic properties are notoriously bad. The reason for this may be found in the fact that architects in general have not given the matter very serious consideration, being content to plan the building for convenience or artistic effect and, if they gave a thought to the acoustics, it was merely to abide by certain ancient superstitions and hope for the best. The inevitable result of such a hit-and-miss method has naturally been a large number of failures.

One of the commonest fallacies which has gained acceptance even among the best architects is that if a certain building possesses good acoustic properties, then all other buildings constructed on the same general plan will also possess good acoustics. This is tantamount to saying that *form* is the only factor determining the final result, whereas it is but one of several and not in general the most important.

After the architect has completed his work and the builders have faithfully followed the plans and specifications, it very often happens that although the general effect is entirely satisfactory, yet the audience cannot distinctly hear the speaker or the music and thus the main purpose of the auditorium is not fulfilled. In such a case the hall is either left in this unsatisfactory state and is a constant source of annoyance to both speakers and audience, or attempts are made to remedy the mistakes that should never have occurred. Now if the architect has not the knowledge necessary to design the hall with a view to securing good audition, it can scarcely be expected that he will be able to remedy the trouble afterwards, so that attempts in this direction are quite often failures and leave the building no better than before.

When the acoustics of a building are found to be unsatisfactory an attempt to improve matters is sometimes made by raising the platform on which the speaker stands. This is often done in churches and in case of a high vaulted ceiling results in a large proportion of the volume of sound being lost to the congregation. Such a plan, although not generally productive of much improvement, has at least a rational basis, namely that of allowing a clear path from the speaker to the audience.

There is, however, another practice in vogue, the origin of which seems as obscure as the reason for employing it; this is the plan of stretching wires or strings across the room. The practice is a very common one and scores of beautiful halls and churches in Canada and the United States have been disfigured

through faith in this hoary superstition, which has not a vestige of reason to support it.

A third method frequently employed is that of hanging curtains or draperies at the back of the stage or about the hall. Such a plan is often effective but loose draperies are very objectionable on account of the dust and germs that they are liable to collect and, at least in the case of music, they are often apt to make matters worse rather than better.

The main factors governing the audition of a hall or church are:

1. Its dimensions compared to its seating accommodation.
2. Its form in reference to certain details.
3. The materials employed in its construction.
4. The arrangement of the heating and ventilation.

Given control of these and the acoustics of the hall is a matter of exact calculation as much as is the strength of its roof and walls.

Excessive reverberation is one of the chief troubles occurring in public buildings and this defect is more pronounced in modern buildings on account of the extensive use of structural steel and concrete; nevertheless it is entirely feasible to so proportion the building and distribute the materials of interior construction that the results will be satisfactory and this without detriment to the building in any way.

The writer was recently called on to examine and if possible improve on the acoustics of the Margaret Eaton School of Literature and Expression in this city. The public hall of this school was an oblong room of about 70,000 cubic feet, having a low stage at one end and a gallery at the other. The main floor seated 300 and the gallery 100 persons. The acoustics of this hall were so bad that musicians and speakers had almost invariably refused to appear there a second time, and the Principal and Board of Directors were most anxious to have anything done that would save the reputation of their auditorium. Tests on the empty room and also in the presence of an audience showed much too great a reverberation with a zone of maximum disturbance across the centre some six or eight feet wide; further, the residual sound of the note from a middle C organ pipe died away without alteration of pitch to the limit of audibility, indicating that there was neither reinforcement nor suppression of upper partials; this would have been almost self-evident from the form of the room and stage. In this hall the believer in the stretched wires had already been on the ground, for at the time that the writer was called to see it there existed a system of some eighty cords stretched from side to side, presenting a most unsightly appearance in an otherwise beautiful room. These were at once removed, the walls were deadened sufficiently to reduce the reverberation 25 per cent., when the acoustics were declared to be perfectly satisfactory and there have been

no further complaints in regard to the hearing in any part of the hall.

Another example of a somewhat similar nature may be given, namely that of Knox Church, Spadina Avenue. In this case the plans had been submitted to the writer and calculations in advance of construction indicated that with some minor modifications the result would be satisfactory. These plans included a gallery on three sides of the auditorium, but the Building Committee, to reduce the cost, eliminated the two side portions of the gallery, thereby changing the amount of surface and the seating capacity. When the building was completed it was found that the acoustics were by no means satisfactory. The plan of raising the pulpit platform and of placing a sounding board over the speaker were both tried without marked improvement. Tests on the building gave a reverberation of about 20 per cent. over that calculated on the original plans. This has been reduced to normal value by panelling the two long side walls beneath the rail and the two inner walls of the transept, some 1,800 square feet in all, and the hearing is very satisfactory.

Other examples might be given but they would not indicate anything essentially different from those stated. The two cases mentioned show that it is entirely feasible to construct buildings in which the acoustics shall be satisfactory and also in some cases to remedy those that have been badly designed. Sound is a form of energy similar in many respects to light and heat, subject to the well established laws of reflection, refraction and absorption and if these laws are intelligently applied there need be no fear of the final result; but when such statements as are contained in the subjoined paragraph published in the newspapers of this city some three years ago, are given to the public apparently in good faith, it is not surprising that failures are as common as successes, for what more could be expected of men who would be responsible for the publication of such nonsense?

The paragraph refers to a well-known building just then completed: "The acoustic properties of the building are its special features. Any sound uttered upon the platform carries perfectly to any point in the auditorium. The glass in the dome is so set in the steel ribs as to prevent vibration, and the girders used in the construction are tuned to a pitch and adjusted to a fixed strain in order that the whole structure may be in tune."

PRACTICAL HINTS ON UNDERGROUND SURVEYING.

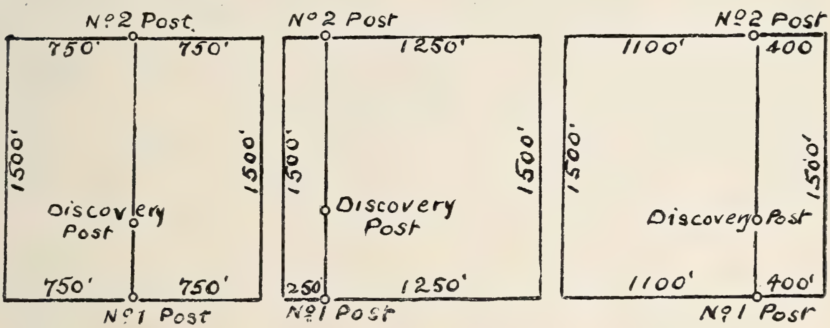
WM. A. O'FLYNN.

The first duty of a man on assuming the position of surveyor to a mining company is to check up the work of his predecessor provided the underground workings are not too extensive. In case the mine were entered by a long tunnel it would be best to make a complete resurvey, connecting it with the surface lines.

Then I would advise the boundary lines to be resurveyed and all corner posts located as the surveys of mining claims are not always paragons of perfection. This will give you the correct data for your maps.

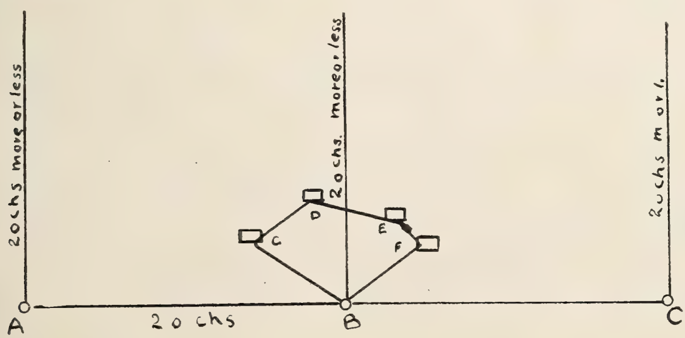
Familiarize yourself with the different systems of laying out mining claims, as they play an important part as to where you should start your survey to connect with the underground workings.

In British Columbia, Saskatchewan, Alberta and Northwest territories a quartz claim is laid out thus:



In this system connect up and tie in all your work to No. 1 post.

In Ontario in the surveyed districts owing to the system in vogue it would be best to start from one of the posts on the south boundary, e.g., suppose you had four shafts to connect, located thus:



In this system start from which ever post is nearest the shafts, i.e., B, and connect with a traverse survey tying in at B. You can assume your astronomical bearing from A B or get it by an observation. Assign the proper bearing to the respective lines, using latitudes and departures for plotting your work. If your latitudes and departures close correctly you know that your work has been correct and this will obviate the necessity for resurveying.

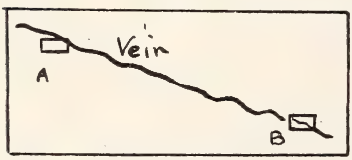
The reason for starting from the posts is that you will be able to see by your map the exact position of the workings so that they will not be encroaching on your neighbor's property nor he on yours and hence prevent litigation, which is not uncommon in mining. If such is the case there is always a resurvey by some O.L.S., P.L.S., or well-known surveyor of repute and the correctness of your work adds to your success. Never leave any loopholes.

There are five different methods for connecting the surface surveys with the underground workings.

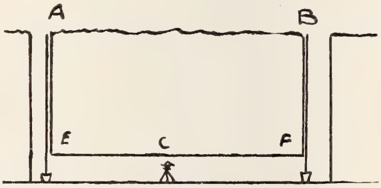
First by means of a slope or adit-level—When the underground workings are connected with the surface with an adit level or a slope, the surface survey is carried into the mine through this opening. Up to 50 deg. there is not much lifficulty other than the danger of slipping, but when the slope reaches 60 deg. your line of sight in most transits will strike the vernier plate, and then it becomes impracticable to continue the work without employing some indirect method. (See method No. 6.)

Second, by means of two shafts—When the shafts are vertical and can be connected by a straight line.

Example:



Plan
Fig 5



Elevation
Fig 6

First establish points at A and B in a straight line from your last hub if possible, if not, set up very near A or B, establish the further one, transit the telescope and establish the other. Reverse instrument and repeat the operation. Always check your work.

Then drop plumb lines down the shafts at A and B. For attaching your plumb line a piece of flat iron 14 in. x 1½ in. x ½ in. which can be fastened to the timbers and set in place by the transit is advisable.

The best material to use for a plumb line is fine piano wire and if you are surveying a deep shaft it is imperative to have it.

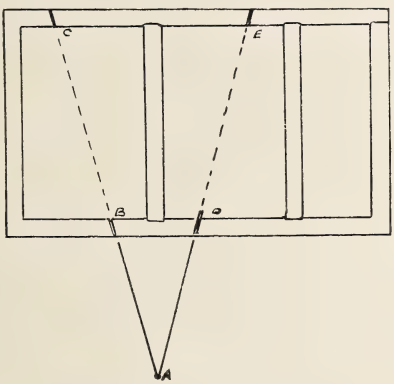
The plumb-bobs should weigh from 5 to 9 lbs., and in order to prevent the wire from breaking when lowering it is advisable to use a lighter weight to lower it with, say about 1 lb.

The bob is attached and placed in a tub or barrel of water, or oil, the latter being preferable if obtainable, so as to reduce the oscillation.

You then descend and set up the transit at C, Fig. 6, getting some one to stand behind one of the plumb lines and sight the instrument in line as correctly as possible. Then sight on A or B and transit the telescope. If the vertical cross hair is in line with the plumb line you must be in the straight line joining A and B, that is, provided your transit is in perfect adjustment, which it should always be in mine surveying; if not, move the transit by means of the moveable head in the necessary direction, then sight on A or B transit telescope and sight on forward plumb line, repeating the operation until you get in the straight line.

Then establish points in the roof at E and F, Fig. 6, or at a point which will be conveneint to start off your work. E and F will have the same bearing as A and B, and from E F you can commence your underground work.

Third, by means of four plumb lines.



This method is applicable in a double compartment shaft of which the above is a plan.

Establish the point A in some suitable place near the top of the shaft, taking care that the conditions underground will enable you to lay out the work below as above.

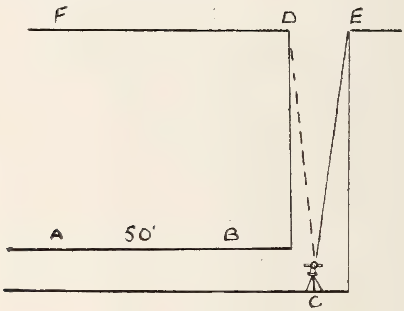
Then establish the points B, D, C and E, using the iron hanger. (See method No. 2.)

Measure and record distances AB, BC, AD, DE, BD and CE, also measure and record the angle E A C and check your readings by doubling the angle several times. Then drop the plumb lines as stated hereinbefore in method No. 2.

Care should be taken to see that the plumb lines hang full. Then check the distances BC, DE, CE and BD. Then by means

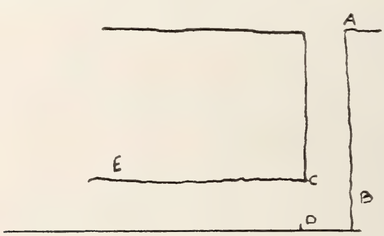
of a straight edge placed as near as possible to the plumb lines B and C measure off BA and establish A, then do likewise at E and D. This will locate approximately the point of intersection A. A large block of wood is suitable to locate the point of intersection A. Two pieces of fine wire can also be used. Then set up the transit at A and measure the angle CAE and if it agrees with the angle observed on the surface you must be over the point of intersection A, if not, move the transit until you have by repeated trials obtained and agreed with the angle established on the surface. Then recheck all the distances AB, BC, AD, DE, BD and CE again. Now if all your measurements agree with the surface ones you have evidently carried down the azimuths of the lines AC and AE, and from these you can commence your survey by establishing fixed points at suitable places, in the roof.

Fourth, by means of a transit.



Put a spud in the roof at B and set the transit up in the middle of the shaft at C, and establish the point A by putting a spud or wooden plug in the roof and in the same straight line as CB, then by means of a prismatic eyepiece establish the points D and E, then go up on the surface and at a distance FD nearly equal to AC set up the transit in a straight line with DE. This having been accomplished, you can connect up with the surface survey.

Fifth, by means of an auxiliary telescope.

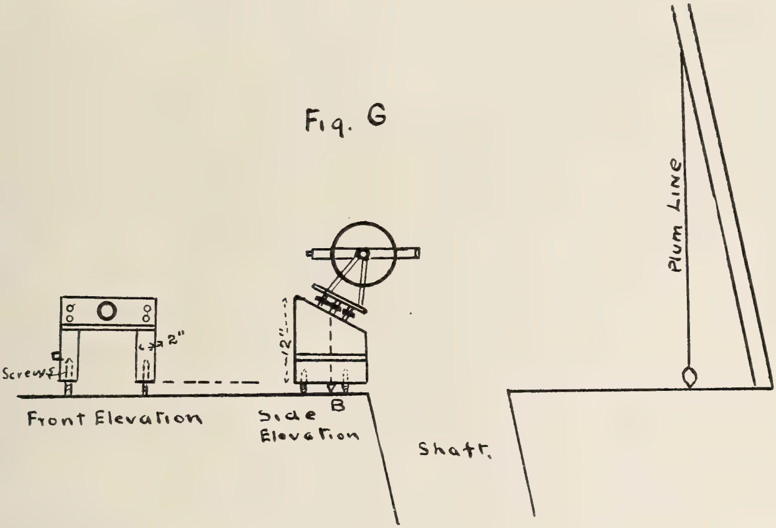


Set the transit up at A so that you can see vertically downwards and establish the points B in the timbers about 8 ft. from the ground point C in the roof and the point D directly under

C, then descend and set up at D. Lower the telescope and the cross hair out to be in line with a plumb line hung at B, then transit the telescope and establish a point at E and set up, then you hang another plumbob from C then E and B ought to be in the same straight line. These are checks which can be eliminated if the instrument is in perfect adjustment.

Sixth, a method for surveying down an inclined shaft greater than 60 deg.

Fig. G



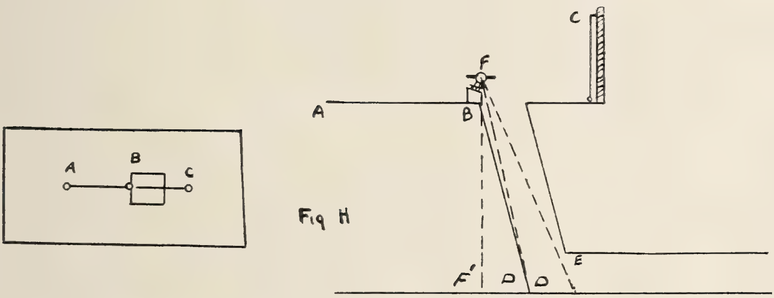


Fig H

Establish the point A and set transit up at that point, then establish the point B a few inches from the mouth of the shaft and the point C in the same straight line, and about 20 ft. above the ground or at such a height that the telescope of the transit will be elevated to an angle greater than 45 deg. From this point drop a plumb line. Then set up at B, using a device such as Fig. No. 9 shows, provided you have a transit which is placed in its box by means of screwing it on to a board. You can attach this board to two pieces of wood cut at an agle of about 25 deg. Having two screws on each piece which can be screwed up into the wood by means of pliers, so as to adjust

the wood device and get it level, using a carpenter's level therefor. Then get approximately two levelling screws of the transit at right angles to the plumb line hung from C, and level up the bubble which will also be at right angles to C. Now sight on C and depress the telescope and if the transit is level in a line at right angles to C, and also the axis on which the telescope revolves, the vertical cross hair will follow the plumb line from the point C to the bob, if not you will have to shift the levelling screws and by trial obtain the aforesaid position. Now using plumb line from C as a foresight, establish point D in the timbers about ten feet off the ground and also the point E on the floor. Then level the telescope or see that the telescope is parallel to the horizontal plane. This can be done by means of the level directly under the telescope, and with the telescope in this position observe the angle on the vernier, then depress the telescope and observe the angle that FE makes with the horizontal and then by subtracting the angle observed when the telescope was in a horizontal position. You will have the exact angle of depression, also observe the angle that FD makes with the horizontal and proceed as before. Then subtract the angle the FE makes with the horizontal from the angle the FD makes with the horizontal and you will have the angle DFE which is required for solution of the triangle, and by subtracting the angle that F makes with the horizontal from 90 deg. you will obtain angle EFF^1. Now having solved the triangles you have the distance F^1E which, added to B plus the little distance that the centre F is from B, you have the exact chainage of E.

Then descend and set up, using tripod over point E and hang a plumb line from D and using it as a backsight you can continue your survey underground, or the tripod could be placed so as to give the transit the required tilt of about 25 deg. and I would suggest placing two levelling screws of the transit on line AB back from the mouth of the shaft and the other two at right angles to the line AB.

I would add that in mining a transit of low power is preferable on account of the short sight. It must always be in perfect adjustment, and it is absolutely necessary that all the work, i.e., distances and angles should be checked several times by the methods which are taught by the faculty. And when producing a line always reverse the telescope and always use as near as possible equal distances between stations. Now as to levels. When an engineer starts in a new proposition and has a number of shafts to sink and probably to connect hereafter, he must have correct levels so that he can have the drainage coming to which particular shaft that he desires, and thereby having a down grade for his ore which will enable the muckers to do more. Another economic value would be that he would not have to buy and install a pump, as occurs in some places and in Cobalt where the 150 level of one shaft is from 5 to 10 ft. different in elevation. It would also be advisable to establish a permanent bench mark.

OBITUARY.

Charles Goodfellow Milne, B.A.Sc., '93.

Charles Goodfellow Milne was born October 8th, 1870, at "Hillside," in the township of Scarborough, York County. He received his high school education at Markham and Whitby, and entered the School of Practical Science in 1889. In 1892 he graduated in the course of mechanical and electrical engineering, and took his B.A.Sc. degree the following year.

Charles Goodfellow Milne

At that time structural engineering offered him the most promising opening, and he spent several years in and around Pittsburg and Elmira at structural drafting. In 1895 he returned to Canada and became connected with the Hamilton Bridge Works Co., where, in a short time, he was made chief draftsman. He assumed the position of chief engineer of this company in 1901, which position he held at the time of his death.

His health had been poor for the last year or so, and in spite of a holiday trip to Panama in the spring, he was taken down with typhoid fever early in July, 1909. He never recovered from the effects of this attack, and died December 13th of the same year at the age of thirty-nine. He married in 1891, and leaves a widow and three daughters.

Of the many engineering works which were carried out under his direct supervision, perhaps the best known are the St. Maurice River railway bridge over the gorge at Shawinigan Falls, Que.; the Canadian Pacific viaduct at Parry Sound, Ont.; the Canadian Northern Railway bridge at Prince Albert; the head office of the Bank of Hamilton, Hamilton, Ontario; the Traders Bank Building, Toronto, Ontario; and the Grand Stand, Toronto Exhibition Grounds.

His ability as a structural engineer was equalled by his

knowledge of electrical and mechanical branches. Probably his versatility is best shown in the plant of the Hamilton Bridge Works Co., of which practically every detail was designed by himself. His death cut short a career which was always a credit to his alma mater, and the profession, and which gave every promise of being a very brilliant one.

William E. Cole.

Born August 5th, 1883; deceased December 31st, 1909.

William Ernest Cole received his public school education at Lucasville. On completing this he attended Sarnia Collegiate Institute, where he secured a teacher's certificate. After attending model school at Sarnia he spent three years teaching public school in Sarnia township.

William E. Cole

Having decided to make engineering his life work, he registered at Toronto in the fall of 1905 in the department of Civil Engineering. During his college days he made many friends by his cordiality and unceasing good humor. He was an enthusiastic football player and a hearty supporter of all college athletics.

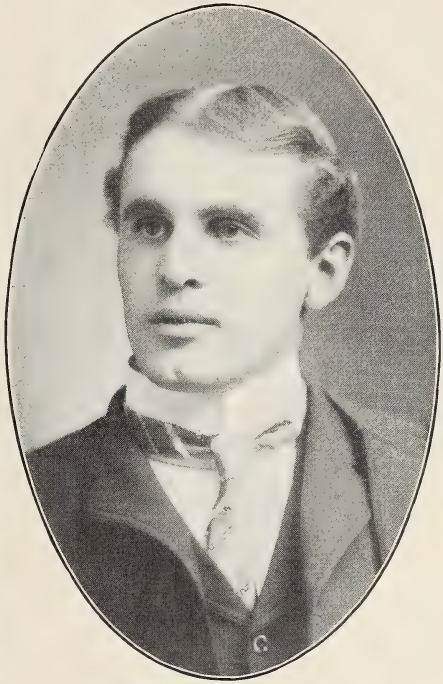
When he took a position on the Transcontinental Railway soon after graduating in 1908, he entered into the work with his characteristic enthusiasm and soon established for himself a record for rapid and accurate engineering work. He was rewarded by promotion and his prospects in the engineering field seemed very bright, but about the first of December, 1909, he contracted typhoid fever. He was taken to New Liskeard hospital where he received the best of care and medical attention. Having passed the crisis of the disease he was thought to be progressing favorably when he took a relapse which resulted in his death on the last day of the year.

The funeral was held from his home in Sarnia and the many

floral tributes testified to the high esteem in which he was held by his friends there.

William J. Larkworthy.

Early in the summer of 1909, one of the most energetic and promising graduates of the Faculty of Applied Science and Engineering passed away in the person of William J. Larkworthy.



William J. Larkworthy

Mr. Larkworthy was born at Mitchell, Ont., in 1879, where he received his Public and High School education and where many busy and happy hours were spent as a boy indulging a pronounced taste for experiment and invention. All his pocket money went to purchase material for engines, boats, electric lights, telephones and a great variety of other mechanical and electrical contrivances in which he had an all-absorbing interest. It was but natural, therefore, that when the time came to choose his life-work, he should select electrical engineering and accordingly he entered the School of Practical Science at the age of eighteen. Ill-health compelled an absence of a year after two years of student life, but he returned and graduated with the class of 1903. A year of practical work with the Bell Telephone Company then followed, after which he took the post-graduate year, obtaining his degree in 1905. Those who were with him in the last days of the session of 1904-1905 will well remember the extraordinary energy which he gave to the project of forming the class into a permanent organization, and it is owing to him more than to anyone else that the arrangement was finally effected.

As soon as college days were over he began work in earnest with the Niagara Falls Hydraulic Power and Manufacturing

Co. with whom he spent over two years, engaged largely upon original investigations of the possibilities of the electric furnace in manufacturing processes. Following this he became president of the Electric Navigation Co. of Buffalo, but after three months his health failed and he was sent to Denver in the hope that recovery might be brought about. Unfortunately the desired result was not realized, and he was brought home to Mitchell, Ont., where after a year spent in a tent he finally passed away. To his classmates and all who came in contact with him there remains a pleasant memory of a buoyancy and optimism which were singularly well expressed in his student name—"Lark."

Wm. E. Elwell.

Born Nov. 13th, 1880; died Sept. 3rd, 1909.

Wm. E. Elwell, whose death occurred in Ottawa on Sept. 3rd of last year, was born in that city on November 13th, 1880, and was consequently in his 30th year. He was the son of Rev. Wm. Elwell, now of Chicago, Ill., a minister of the Catholic Apostolic faith.

Mr. Elwell entered the School of Practical Science in the fall of 1899, and graduated with the class of 1902. During his academic career he stood high among his fellows as a student. At the same time he took a prominent part in athletics, being very successful in upholding the honor of the University as a member of the Track Club. He was also a member of the "School" hockey club.

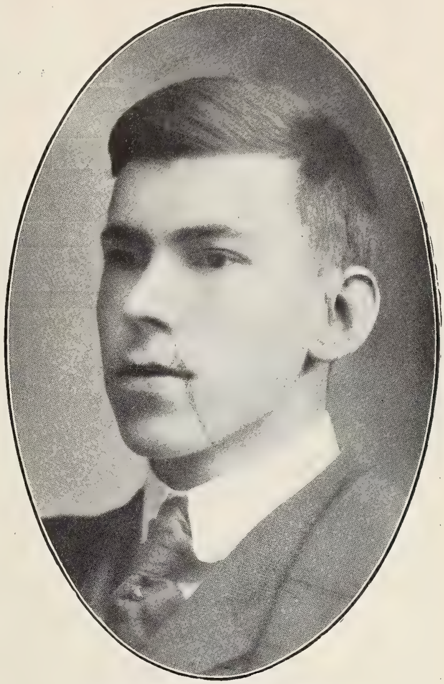
After graduating he went to New York, being employed with the New York Edison Co., but the inside work not being congenial he returned to Canada and entered the Topographical Surveys Branch of the Department of the Interior in October of 1905.

On Sept. 3rd, 1906, he married Miss Ida Thornton, of Whitevale, Ont. Needless to say, the taking away of one who in early manhood gave promise of such a useful future, has occasioned general regret among a wide circle of friends.

John C. P. Molesworth.

John C. P. Molesworth was born at Toronto, January 26th, 1888, received his preliminary education at the Model School, Toronto, and later obtained honor matriculation from Jarvis Street Collegiate Institute, entering the Faculty of Applied Science of Toronto University as a student in Architecture in

1905. The high character of work submitted by him may be recalled by referring to the class lists of his year. Each year he obtained Honor Standing in his work and in 1908 received the diploma with honors.



John C. P. Molesworth

From the time of graduation till the time of his death he was identified with the firm of Chadwick & Beckett, architects, Toronto.

It is sufficient to mention the keen interest which he placed in athletics. As a member of the Argonaut Rowing Club, he availed himself of the privileges at his disposal for physical development. His interest, however, was divided with other sports than that mentioned, both at the University and at the club in Oakville.

During his University career he was a member of 2nd Field Company, Canadian Engineers, and later he identified himself with "K" Company, Q. O. R. In both these regiments he held non-commissioned rank and displayed live interest in their work.

As a member of St. Luke's Church he showed an interest in the various institutions of the parish and it will be regretted that his opportunity for service has been cut off by an untimely accident.

His fellow graduates of 1908 maintain the fond recollection of one whose every manner was frank and true, showing no evidence of flattery to friends and possessing to an admirable degree the quality of reservation.

Though absent from our midst, his personality remains.

L. A. McLean.

We regret to have to record the death of L. A. McLean, B.A.Sc., '08, at Ottawa on February 14th, 1910, under the sad-

dest of circumstances. During the vacation of his school course he was engaged on D.L.S. work and the high grade of his work, as told by all of those to whom he was assistant, promised great things for his future. All of those who knew McLean in his school course deeply regret his untimely death and his parents have the heart-felt sympathy of every School-man.

Stanislas Gagne.

On April 15th, news reached Toronto of a terrible accident in the construction camp of the Ha! Ha! Bay Railroad in Quebec. Additional interest was added by the fact that a Toronto man, Stanislas Gagne, was one of the victims. Details show that a remarkably large and premature dynamite explosion caused an immense landslide, which buried the construction camp at the foot of a hill, where the victims were sleeping.

Stanislas Gagne

Mr. Gagne was a partner of the firm of Gagne, Jennings & O'Brien, engineers and contractors. He was about thirty-one years of age. In 1901, he graduated from the School of Practical Science and at once became associated with the late W. T. Jennings, who considered him one of his cleverest engineers. He was Mr. Jenning's chief assistant in the Niagara Power construction work and became chief engineer of the right of way. After Mr. Jennings' death his son, Gordon T., joined Mr. Gagne and the firm had a great deal to do with the Toronto, Niagara & Western Railway. Mr. Gagne was also the designer of the Fort Erie and Buffalo bridge, and was associated with the Toronto Suburban Railway, the Vancouver, Victoria & Eastern Railway, and other projects.

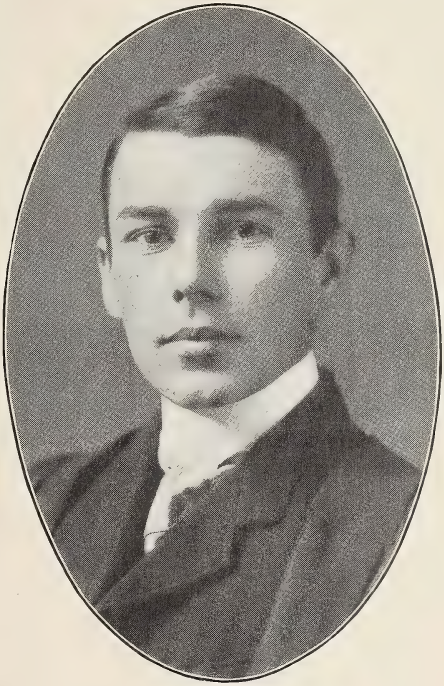
On obtaining the contract for the construction of the Ha! Ha! Bay Railroad, F. N. O'Brien joined the firm.

Mr. Gagne was one of the School's most loyal graduates and it was largely through his influence that such a number of French Canadians have in the last few years entered the University.

He was unmarried. His father, Francois Gagne, who is about sixty years old, lives at St. Joseph d'Alma, Quebec. The sympathy of all School men goes out to him and his in this their hour of affliction.

Milton Bates.

The unexpected death of Milton Bates at his home in Chatham, Ont., in November of last year came as a shock to a large circle of friends and acquaintances. He was of unusually robust constitution, but suffered from a relapse of typhoid fever which he contracted in the Cobalt country early in the fall. Mr. Bates was a graduate in Mining of the class of '06. He returned in 1907 to take his degree of Bachelor of Applied Science. Before entering the School, Mr. Bates had considerable experience in the copper mines of northern Michigan and during his summer vacations. He spent most of his time after graduating prospecting in Northern Ontario or with the firm of H. T. Routly & Co. as surveyor at Haileybury. Mr. Bates was of an unusual congenial disposition and made a host of friends for himself while taking his course at the University, and was one of the best known men of his year. His pluck and perseverance made all his undertakings successful and no doubt, had he been spared, he would have made a name for himself in the country.



Milton Bates

ADDRESS OF W. D. BLACK, RETIRING PRESIDENT OF ENGINEERING SOCIETY.

Gentlemen,—This is the last opportunity I shall have of addressing you as your president. I wish to thank each one of you for the personal support and consideration you have shown me during my term of office.

The past year has seen some important changes in the affairs of the Society and with your permission I will review some of the work which has been done.

The Supply Department has been completely revised by enlarging it and introducing a new business system, so that we now have a store, run on thoroughly business lines and kept open during all school hours. A permanent sales clerk was employed, a cash register purchased and an auditor employed to audit our books and introduce a new system of book-keeping so that we now have an absolute check on funds and stock.

Several new lines of goods have been handled this year, including a text-book by one of our lecturers. This marks a new epoch in our work and I think much better results could be obtained if each of our professors were to publish a text-book thoroughly covering his branch of our studies. The Engineering Society is now in a position financially to aid the lecturers in this work and thus do away with the multitudinous number of printed notes in pamphlet form, which has been advocated in the past.

The paid secretary, Mr. MacKenzie, resigns that position this spring. Under his editorship, our journal, "Applied Science," has been a credit to the Society and to the University. It forms a splendid link and tends to promote the most cordial relations between graduate and undergraduate. In the past the paid secretary has also been assistant registrar of the Faculty, but it has been thought better to employ one who could devote his time wholly to the interests of our Society and thus be in a position to relieve your Executive of much work. Mr. H. Irwin has been appointed to this position. Under him I feel that "Applied Science" will not depreciate and that the best interests of the Society will be advanced.

Our annual dinner was a success. At it we entertained eighty of the most prominent members of the Canadian Manufacturers' Association in an effort to bring about a closer relationship between the School and these captains of Canadian industries. That the attempt was to some extent successful was shown by the letters received from engineers and manufacturers expressing appreciation of our efforts and congratulating us on their success.

The papers read before the Society have been of great interest and the meetings well attended. It says much for the loyalty of our graduates to their Alma Mater and for their

appreciation of the Engineering Society that two have come from New York, one from Montreal and one from Pittsburg at the expense of considerable time and money especially to address the Society and to give us the benefit of their experience.

The second vice-presidents have worked loyally and unselfishly for the welfare of their various sections. Good papers have been the rule and the excursions to various manufacturing establishments in the city, arranged by the vice-presidents, aided by members of the staff, have been attended with much profit.

The most cordial relations have existed between the students and the staff whom I have always found anxious to do everything possible for the advancement of the Society. Your thanks are especially due Dean Galbraith, Professor Wright and E. A. James, editor of the Canadian Engineer, who have aided your Executive to an extent perhaps not appreciated by you, in carrying out the undertakings of the Society.

One real grievance which I think we have is in the condition of our library which is more or less a joke as it exists at present. Most of the books contained in it are relics. The University is at present expending a great deal in a central library but apparently the need of modern engineering literature has been overlooked.

I have had reason to congratulate myself on the very able and strong Executive with whom I have been associated in carrying on the affairs of the Society. It has been a pleasure to work with them and to them belongs the credit of what has been accomplished this year. I recommend for your unstinted approbation the members of that Executive. I congratulate you on your choice for the coming year and feel confident that the best interests of our Society will be advanced under their administration.

In conclusion, gentlemen, let me thank you for the honor you have done me, and which it has always been my honest endeavor to merit.

I take great pleasure in presenting to you your president-elect for 1910-11, Mr. A. D. Campbell.

TREASURER'S REPORT

The finances of the Society are in a very healthy state, the balance sheet showing a surplus of two thousand eight hundred and sixty-two dollars and fifty-eight cents.

APPLIED SCIENCE, this, year, charging the Society for copies distributed to the undergraduates, more than paid for itself.

The supply department was under heavier expense this year, having a special clerk which enabled it to be kept open at all hours. A cash register has been installed at a cost of $175.00, and alterations made in the layout of the supply department at considerable expense.

The following is a summary of business of the year:—

Cash Account Summary.

To receipts from		
APPLIED SCIENCE	$1,286.81	
Supply Department	6,820.39	
Sundries	1,320.58	
Dinner	492.50	
		$9,920.28
By disbursements for		
APPLIED SCIENCE	$1,601.31	
Supply Department	6,477.27	
Sundries	723.54	
Dinner	764.82	
		$9,566.94
Balance cash as per cash book		$353.34
Undeposited cash	$ 28.50	
Pass book balance	380.87	
Outstanding checks		56.03
	$409.37	$409.37

BALANCE SHEET.

The following balance sheet shows the finances of the Society for the year ending March 31st, 1910:—

Assets.

Merchandise as per inventory	$1,839.84	
Cash register less 10 per cent. depreciation	157.50	
Accounts due Supply Department	60.80	
Accounts due APPLIED SCIENCE (advt.)	568.71	
Accounts due APPLIED SCIENCE (cuts)	43.00	
Sundry accounts	103.25	
Balance cash book	353.34	
		$3,126.44

Liabilities.

Accounts outstanding APPLIED SCIENCE	$ 263.96
Surplus	2,862.48
	$3,126.44

Surplus March 31st, 1910	$2,862.48
Surplus March 31st, 1909	2,040.66
Net gain for year	$ 821.82

Respectfully submitted,

F. V. MUNRO,

Treasurer.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

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Editorial

In Conclusion

With the publication of this issue, the editor of Applied Science lays down the official pen. Since its projection three years ago, he has seen the journal grow financially from an experiment to an assured success, and if the judgment of the public is to be relied upon, it has attained a measure of journalistic success also. The arguments advanced three years ago in favor of its inception have been vindicated and Applied Science will continue to be issued monthly during the academic year. As such, it brings promptly before its readers the papers read before the Engineering Society. This was quite impossible during the old regime. As an advertising medium, it has appealed to the business community; as a journal, it permits of the publication of items of news value to its readers and of

the propagation of an editorial policy on topics of vital interest to the Engineering Faculty.

In leaving the service of the University and the Engineering Society to accept other responsibilities, the editor separates himself from a work and an environment which have been exceedingly pleasant. His associations with the staff, the Executive of the Society and the student body have been most amicable, and under its management-to-be, he wishes APPLIED SCIENCE the greatest possible measure of success.

A. D. CAMPBELL IS PRESIDENT OF ENGINEERING SOCIETY.

Election night—long will it be remembered by the School man, being as it is the last, the very last, on his list of social functions for the 1909-10 college year. It was his conception of what society circles should commend as ideal for "the younger set," and moreover he was right at home, dressed to suit the occasion. Much credit is due those whose painstaking endeavors rendered the event so entertaining.

A. D. Campbell

The hobo band was a charming feature. "Do you want some more music?" asked a member. "No—no more music; just play something."

Paper fights and blindfold boxing were most amusing numbers, Jimmie Murton helping on the fun by his unique refereeing. A wrestling bout between Hastings and Alexander was very interesting and exciting. The basketball game between Junior and Senior School resulted in a win for the former. It was lively to the extreme, and was in fact a good exhibition of the game. The tug-of-war between the first and second years brought tears to the eyes of those holding down the drafting-tables. and the silence was deafening as victory was gradually induced to settle upon the men under the ban of the unlucky number. In the second struggle it was anybody's rope until Mike Barry calmly picked up an end, executed a finger hitch, and, cheered on by Jimmie Stewart, pulled both sides to defeat.

GRADUATING CLASS IN ENGINEERING, 1910—UNIVERSITY OF TORONTO.

Distinguished spectators there were, members of the Engineering alumni, who dropped in after their downtown dinner. Upon the platform, everybody was a Manchester Exchange member and everyone else a cotton king, and great were the falls thereof.

The voters, everyone, reached the polling booths through the equivalent of fire and water, voted as they thought best, and withdrew (as others thought best), cherishing a couple of apples and oranges, picked up en route. With a view to evaporating spontaneously accumulated moisture, each proceeded to hide his person in the cloud of grey from the corn-cob, similar to the one which added grace and bearing to the countenance of everybody else.

Soon the returns began to mount the stairs, arm in arm with Dolly Black. Each victor, in his turn, was borne upon the shoulders of increased enthusiasm and hilarity to a table most difficult of access, from whence he endeavored, first to descend, second, to rain floods of thanks upon ears already deafened from within. Then, filling up the pipes once more, we meekly and peacefully pushed them homeward.

The following is a full list of the election results:

President, Angus D. Campbell; 1st Vice-President, Ross L. Dobbin; 2nd Vice-Presidents—Civil and Arch., H. M. Murphy; Chem. and Mining, E. A. Freeland; Elec. and Mech., F. H. Downing; Treasurer, W. A. Gordon; Corresponding Secretary, A. H. Munroe; Recording Secretary, E. J. Ritchie; Curator, R. B. Chambers; 4th Year Representative, Jas. McNiven; ; 3rd Year Representative, Wm. Curtis; 2nd Year Representative, E. R. Gray; Senior Representative to Varsity, P. C. Cherry; Junior Representative to Varsity, P. L.

W. J. White, '08, has been appointed assistant district engineer for the Boston, Mass., office of the General Electric Co.

A. C. Johnston, '94, is vice-president and chief engineer of the J. M. Dodge Company, Philadelphia.

N. Levi Crosby, '05, is with the McClintic-Marshall Co. at their Chicago office.

Geo. H. Power, '01, and Willis Chipman have entered partnership under the firm name of Chipman & Power. Mr. Power will have charge of the western business with headquarters at Winnipeg. A. E. K. Bunnell has taken a position with this firm at Weyburn, Sask.

J. J. Spence, '09, is with Smith, Kerry & Chace on Hydro-Electric Development at Toronto.

A. C. Spencer, '07, is mechanical engineer with the McClary Mfg. Co., London, Ont.

WHAT THE GRADUATES ARE DOING

W. N. Moorehouse, '04, is at present travelling in Europe studying art and architecture.

L. W. Morden, '05, sales engineer with the Canadian Westinghouse Co. with headquarters at Toronto.

W. P. Murray, '06, for part of the year fellow in drafting, has taken a position with the Dominion Bridge Co., Lachine Locks, Que.

E. W. Murray, '07, is engineer on construction of the hydro-electric power plant at Stratford with the contractors.

W. G. Nicklin is assistant superintendent with Dahm & Kiefer Tanning Co., Grand Rapids, Mich.

W. deC. O'Grady is engineer with the Gas Traction Co., Ltd., Winnipeg.

E. W. Oliver, '03, is assistant chief engineer of the Canadian Northern Railway Co.

J. P. Oliver is engineer-in-charge of construction of the Chalmette Sugar Refinery for the American Sugar Refining Co. at Arabi, Louisiana. The plant is a $5,000,000 one with a capacity of 12,000 barrels of refined sugar per day.

E. H. Phillips is district engineer, Department of Public Works, Saskatoon, Sask.

E. M. Proctor is with the Canada Foundry Co. at Davenport, Ont.

A. F. Ramsperger, '09, is a draughtsman with the Toronto Iron Works, Ltd.

W. B. Redfern is resident engineer for Willis Chipman on the sewage system at Orillia, Ont.

C. W. B. Richardson, '07, is in the Motive Power Department of the C. P. R. at the Angus shops, Montreal.

R. C. Ross, '06, is assistant on the Deep Waterways Commission Survey with headquarters at Ottawa.

R. B. Ross, '05, is with the International Marine Signal Co., Ottawa.

H. E. Rothwell, '07, is chemist with the Standard Varnish Works, El mPark, Staten Island, New York.

A. Sedgwick, '09, is engineer-in-charge of the Dog Lake storage works, which regulates the flow of waters of Dog Lake west of Port Arthur.

M. R. Shaw, '09, is chemist with the Dow Chemical Co., Midland, Mich.

F. R. Smith, '07, is engineer for the Canadian Gowganda Silver Mines, Godganda, Ont.

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